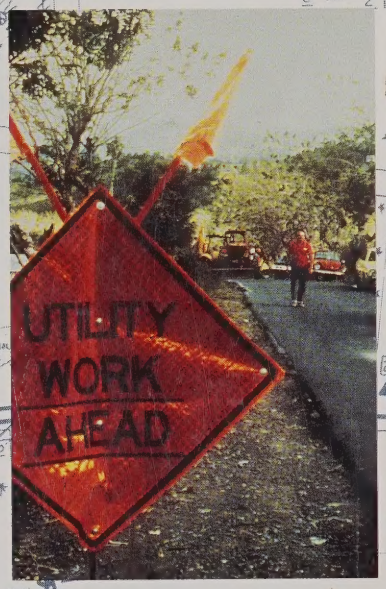
4TH EDITION

Cable Construction Manual

For CATV and Broadband Systems



Published June, 1994

CommScope
General Instrument

4th Edition

Cable Construction Manual

For CATV and Broadband Systems

CommScope
GI General Instrument

CommScope, Inc.
General Instrument Corporation
P.O. Box 1729
Hickory, North Carolina 28603-1729

Published June, 1994

CommScope Cable Construction Manual

The information and procedures presented in this manual are intended to be a helpful guide for the handling and installation of coaxial and fiber optic cable for CATV and other broadband systems. It is not intended to be applicable or suited to every circumstance which might arise during the construction phases of CATV or other broadband system installations. No warranty or liability is implied nor expressed and this manual should not be construed to be a replacement for sound judgment and experience as applied to actual field circumstances.

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GI General Instrument

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Shipment of CommScope Cable Products

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1.0 General

CommScope uses the most advanced loading and shipping techniques available to ensure the safe transportation of customer's orders.

Three methods of shipment are used for CommScope products. Shipment will be made by the CommScope transportation division, common carrier or containerized freight for overseas shipment.

2.0 CommScope Transportation Division

The CommScope transportation division, Cable Transport, Inc., maintains a fleet of tractor-trailer trucks, most of which are specially equipped with *Cargomaster®* cranes which allow most cable products that weigh less than 2,000 pounds to be unloaded at the customers' facilities without a loading dock or forklift.

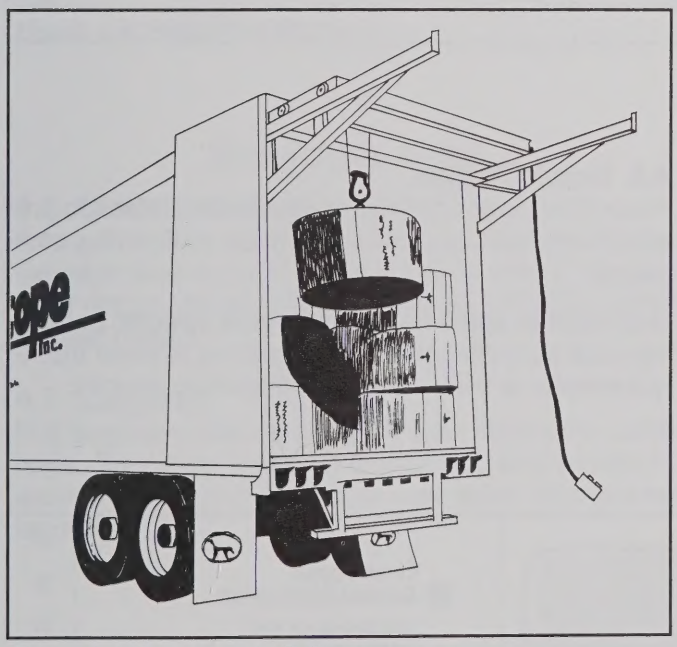


Figure 1.1 Cargomaster® Crane

3.0 Reel Identification

During manufacturing, CommScope cable is tested to ensure that the completed product meets all industry technical standards. The test data is electronically stored during the manufacturing processes for future reference. Each reel of finished cable product is given an identification tag that has a specific *reel number* that can be referenced to the test data that was accumulated during manufacturing.

If a question arises concerning a particular reel of cable, the *reel number* is the key to all information concerning the manufacturing of the cable, including the materials used in the cable and all technical data collected throughout the manufacturing process.

Coaxial Cable

Each tag for coaxial cable (trunk and distribution), provides the following information:

- CommScope's shipping address
- CommScope's *Product Code*
- Cable Grade
- *Length* of cable on the reel
- Product *Description*
- *Tracer Color*
- *Reel Number* and bar code
- Testing spectrum, reel size, cable manufacturing date, and tester's initials
- Special *Comments*

Fiber Optic Cable

Each tag for fiber optic cable provides the following information:

- CommScope's shipping address
- CommScope's Factory Order *(FO) Number*
- CommScope's *Product Code*
- Minimal *Length* of cable on the reel, Note: This may not be the actual length of cable on the reel.
- Product *Description*
- *Tracer Color*
- *Reel Number* and bar code
- Special *Comments*

4.0 Packaging Formats of Cable Shipments

The *packaging format* for cables shipped from CommScope is designed to ensure delivery of the cable without any deterioration of the mechanical, electrical or optical specifications.

Drop cable is packaged in master cartons to improve packaging and storage.

Coaxial Cable

The standard packaging for trunk and distribution cable is as follows:

4.1 Reel Wrap

Reel Wrap, a corrugated cardboard cover, is stapled on the reel flange over the cable. The end of the cable can be accessed directly under the overlap in the *reel wrap* for testing purposes.

4.2 Staybacks

A *stayback* is placed over the end of the cable that is pulled through the reel flange. The *stayback* ensures that the end of the cable pulled through the flange is not damaged in shipping. This cable end will be used when testing the cable on the reel.

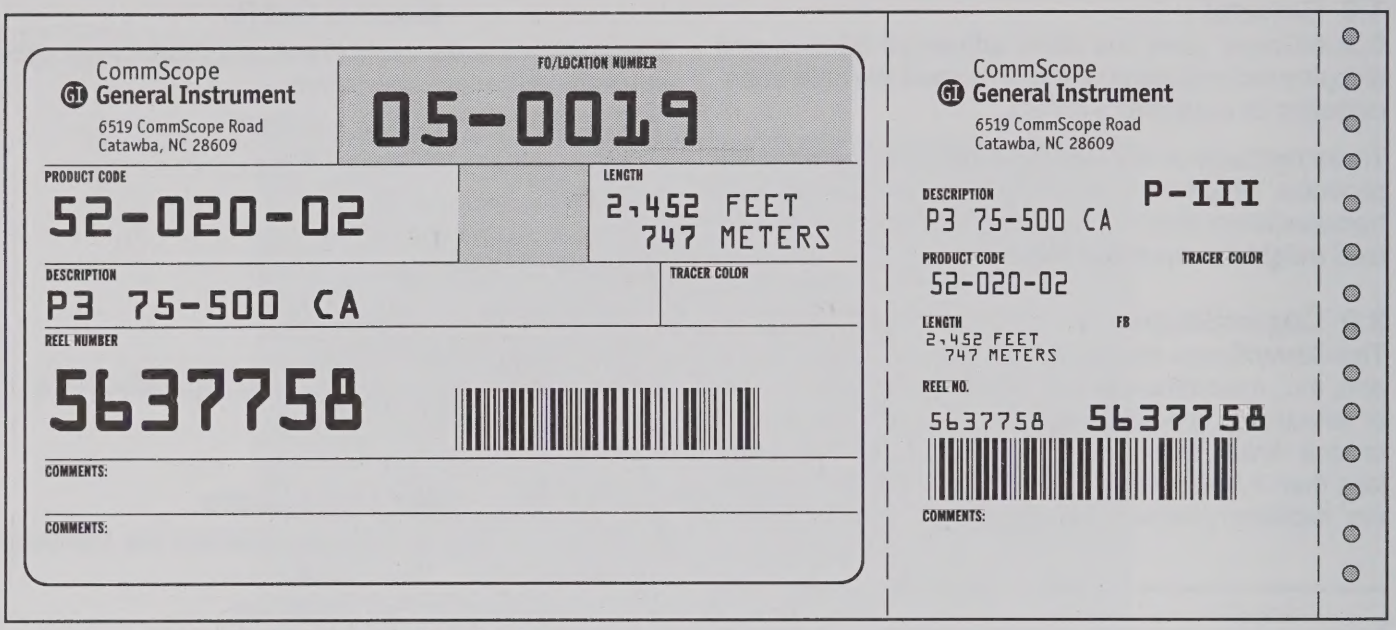


Figure 1.2 Coaxial Cable Reel Identification Tag

4.3 Lagging

Partial or *full lagging* is placed on the cable reel in accordance with the customers specification. All *lagging* is wooden.

4.4 Cable Caps

Cable caps are placed on all cables to prevent moisture contamination.

4.5 Hose Clamps

Hose Clamps are placed on all flooded cables to prevent jacket pull-back and migration of flooding compound.

International shipments may require specific packaging such as full lagging and palletizing to meet the requirements of the customer or importing country.

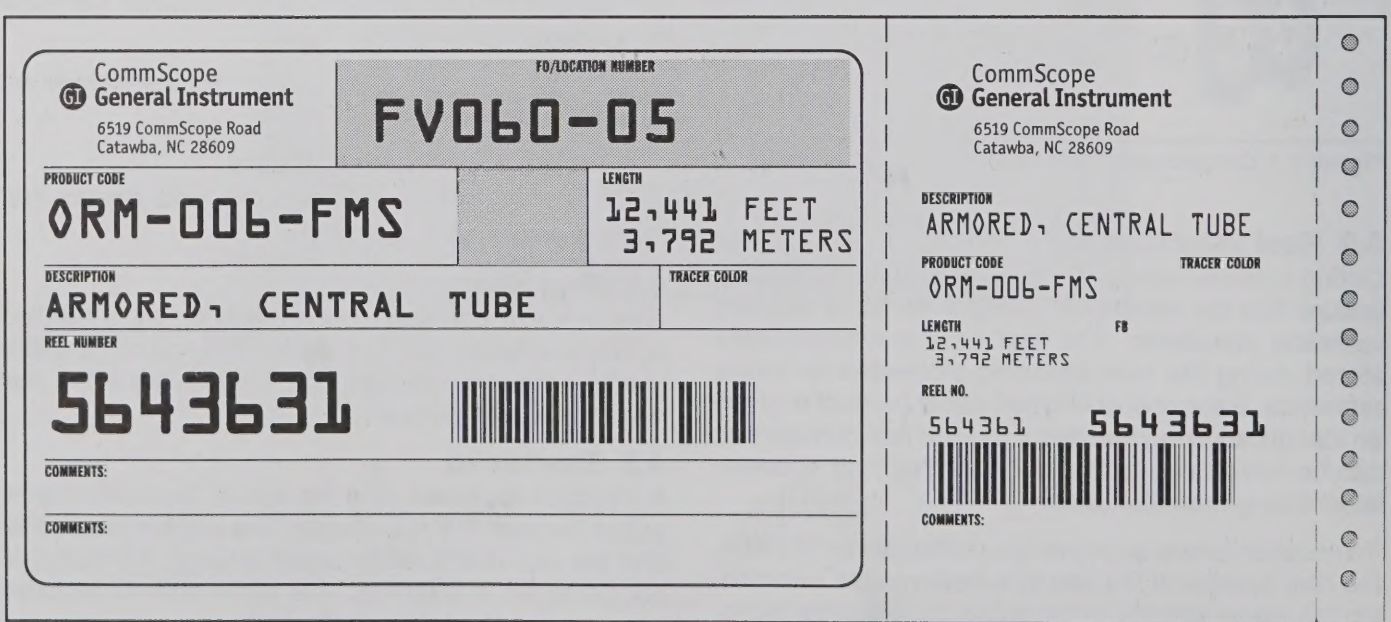


Figure 1.3 Fiber Optic Reel Identification Tag

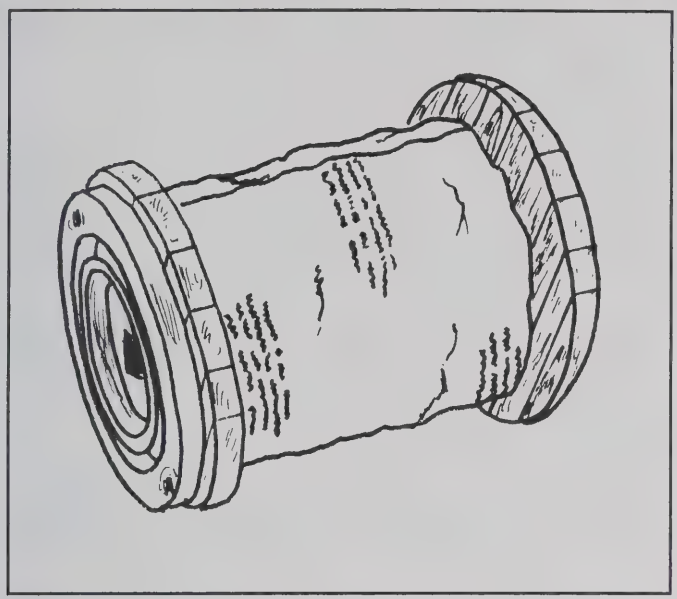


Figure 1.4: Protective Wrap

Fiber Optic Cable

4.6 Cable End Availability

A length of fiber optic cable is pulled through the reel flange to enable testing. The length is coiled into a circular ring on the outside of a wooden reel or the inside of steel reels.

4.7 Lagging

Full *lagging* is placed on all wooden fiber optic cable reels. Two steel bands are installed and tensioned around the *lagging*. Steel fiber optic cable reels are not lagged.

4.8 Cable Caps

Cable caps are placed on all cables to prevent moisture ingress.

4.9 Protective Wrap

A *protective wrap* is placed over and next to the cable to prevent moisture and dirt from filtering down into the cable wraps. This wrap is often referred to as a thermal wrap.

4.10 Certified Test Results

Certified test results are placed in a water resistant envelope and attached to the protective wrap. The location of the test results is marked on the reel.

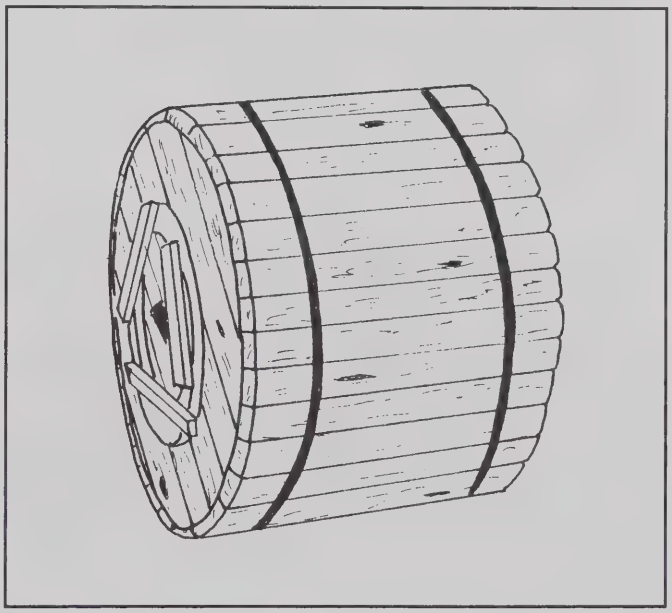


Figure 1.5: Reel Lagging

5.0 Shipping Documents

Consignor

The *consignor* is the shipper of goods.

Consignee

The *consignee* is the receiver of goods.

5.1 Bill of Lading

CommScope will prepare a detailed *Bill of Lading* for every shipment. The *Bill of Lading* is a legal document that must accompany any movement of goods shipped by CommScope. The *Bill of Lading* should provide the following information:

- *Carrier's Name*, Cable Transport Inc., or a common carrier
- *Date* shipped from CommScope
- *Carrier's Number*, i.e. the number assigned by the carrier to the load
- *Shipper's* (CommScope's) control number
- Number of reels, cartons, or pallets
- *CommScope's Order Number.* This is assigned by CommScope to the order.
- *Customer's Order Number.* This number is given by the customer to CommScope when the order is placed.
- Gross *weight*
- Freight terms such as *F.O.B.* (freight on board) factory or F.O.B. destination. These terms define the responsible party for the freight and its cost. The cost is defined as prepaid, prepay and add; or collect.
- *Special Instructions* such as contact person, telephone numbers, specific delivery instructions, etc.
- Signature of *shipper.* The shipper is the person that loaded the freight.
- Signature of the driver

The yellow copy of the *Bill of Lading* will be signed at the destination by a representative for the consignee when delivery is made by Cable Transport Inc.

Common carrier drivers will request signature by a representative for the consignee on a common carrier *Bill of Lading* to indicate delivery of the freight.

STRAIGHT BILL OF LADING — SHORT FORM
ORIGINAL - NOT NEGOTIABLE

DATE _____ 19____
C.O.D. CHARGE { SHIPPER ☐ CONSIGNEE ☐
TO BE PAID BY
CARRIER'S NUMBER
SHIPPER'S NUMBER 419369

CARRIER'S NAME _____

RECEIVED subject to the classifications and lawfully filed tariffs in effect on the date of the receipt by the carrier of the property described in this Bill of Lading

From: CommScope GI General Instrument **AT: CATAWBA, N.C.**

the property described below, in apparent good order except as noted (contents and conditions of contents of packages unknown) marked consigned and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry its usual place of delivery at said destination if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Official, Southern, Western and Illinois Freight Classifications in effect on the date hereof. If this is a rail or a rail water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, including those on the back thereof set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

Consigned to

No. Packages	Kind of Package, Description of Articles, Special Marks, and Exceptions		*Weight (Sub. to Cor.)	F.O.B.
	REELS, CABLE, COPPER, NOI CARTONS, CABLE, COPPER, NOI PALLETS, CABLE, COPPER, NOI			

Subject to Section 7 of Conditions of applicable bill of lading, if the shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement. The carrier shall not make delivery of the shipment without payment of freight and all other lawful charges.

_____ (Signature of consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid"

Received $ _____ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per _____ (The signature here acknowledges the amount prepaid)

Charges advanced

$ _____

†"The fibre containers used for this shipment conform to the specifications set forth in the box maker's certificate thereon, and all other requirements of Rule 11 of the Uniform Freight Classification and Rule 5 of the National Motor Freight Classification."

†Shipper's imprint in lieu of stamp; not a part of bill of lading approved by the Interstate Commerce Commission

SPECIAL INSTRUCTIONS

C.O.D.

REMIT TO:
COMMSCOPE, INC.
6519 COMMSCOPE RD.
CATAWBA, NC 28609

*If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight" NOTE - Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property. **The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding**

per

_____ Shipper, Per _____ Agent

Permanent post-office address of shipper CommScope GI General Instrument P.O. Box 199, 6519 CommScope Road, Catawba, NC 28609, 704-241-3142, Per

Figure 1.6: Bill of Lading

5.2 Shipping Order (Packing Slip)

A *Shipping Order* (packing slip) identifies the quantity of all cable shipped by specific cable type. This *Shipping Order* is found in a clear envelope on the side of one of the packages or reels being shipped.

The *Shipping Order* will indicate:

- *Ship To* address and *Sold To* address
- *Customer Order Number, CommScope Order Number*, and the *Date* of the shipment
- Field *Salesman* number
- Freight (F.O.B.) terms
- *Routing*, i.e. through which shippers the freight will be delivered
- *Quantity Ordered* and *Quantity Shipped*
- Total number of pieces shipped, *total weight*, and the *Bill of Lading* Number

The *Shipping Order* is for the consignee's use in receiving, accounting, and warehousing the cable.

If any questions arise about a shipment after it leaves CommScope, the shipping department will use a copy of the *Bill of Lading*, in conjunction with the *Shipping Order*, to provide the necessary information.

CommScope GI General Instrument

General Instrument Corporation
6519 CommScope Rd. P.O.Box 199
Catawba, North Carolina 28609
704 241 3142

CUSTOMER'S COPY

SHIP TO

SOLD TO

MARK

SHIPPING ORDER

CUSTOMER ORDER NO.	CS ORD. NO.	DATE

SALESMAN	F.O.B.	DATE SHIPPED	ROUTING

ITEM NO.	PRODUCT CODE	U/M	PRODUCT DESCRIPTION	G R	QTY. ORDERED	EST. SHIP DATE WEEK OF	PROC. CODE	QTY. SHIPPED

SPECIAL INSTRUCTIONS

TOTAL PIECES _____ TOTAL WEIGHT _____ BILL OF LADING NO. _____

PLANT INSTRUCTIONS

Figure 1.7: Shipping Order

6.0 Truck Load Quantities

Truck load quantities are identified in Table 1.1.

Table 1.1.: Truckload Quantities of CommScope Products.

Reel Size	Type	# Reels	Product	X	Reel Lengths	=	Truckload
35"	Bare	152	412	X	2,340	=	370,000
35"	Bare	152	500	X	3,000	=	450,000
35"	Jacketed	114	412J	X	2,450	=	275,000
35"	Jacketed	114	500J	X	3,000	=	350,000
41"	Armor	48	412	X	2,450	=	118,000
41"	Armor	48	500	X	3,000	=	144,000
41"	Messenger	72	412	X	2,450	=	176,000
50"	Bare	62	750	X	2,500	=	150,000
50"	Jacketed	52	750J	X	2,500	=	150,000
54"	Armor	30	750	X	2,500	=	75,000
41"	Bare & Jacketed	72	625	X	2,450	=	175,000
57"	Bare & Jacketed	36	875	X	2,500	=	90,000
63"	Bare & Jacketed	20	1000	X	2,500	=	50,000
—	Drop	—	59	X	1,000	=	1,500,000
—	Drop	—	59M051	X	1,000	=	650,000
—	Drop	—	6	X	1,000	=	1,000,000
—	Drop	—	6M051	X	1,000	=	650,000
41"		72	QR540	X	3,700	=	266,000
		36*					133,000
54"		40	QR 860	X	2,500	=	100,000
		17*					42,000
61"		17	QR 1125	X	3,000	=	51,000
*Standing Upright on Rolling Edge		14*					42,000

Delivery and Storage of CommScope Cable

1.0 Delivery

2.0 Unloading Coaxial Cable

2.1 Unloading at a Dock
2.2 Unloading Without a Dock

3.0 Unloading Fiber Optic Cable

4.0 Filing Damage Claims

4.1 Visible Damage
4.2 Hidden Damage

5.0 Storage and Handling of Cable

5.1 Stacking
5.2 Protection From the Environment

1.0 Delivery

When a freight delivery does not match the Bill of Lading, note the difference between the Bill of Lading and the delivered materials on the Bill of Lading. The CommScope Customer Service Department should be notified. CommScope will file all claims when freight delivery does not match the Bill of Lading.

2.0 Unloading Coaxial Cable

Damage can occur during the unloading process. Coaxial cable can be damaged by dropping reels or pallets, or improper handling of reels with a forklift. Common carriers are only required to move the cable to the back of the truck for unloading.

To prevent delays in unloading as well as possible damage to the cable, make sure the CommScope Customer Service Department is provided with any special packaging or delivery requirements, i.e., must be shipped on rolling edge, no shipping dock available, call before delivery, etc. Close coordination with the Customer Service Department should enable sufficient manpower and equipment to be available to aid in unloading the cable shipment. CommScope will make every reasonable effort to comply with a customer's shipping needs.

Stacked cable must be carefully unstacked to prevent damaging the cable and possibly injuring personnel. CommScope drivers are extensively familiar with handling and unstacking the cable without injury or damage. A Cargomaster® crane is useful in unstacking and unloading cable with or without a dock. If a common carrier driver cannot unstack the cable, the driver should be instructed to return to the shipping terminal where equipment exists to unstack the cable. The cable can be reloaded onto the truck on rolling edge.

When the shipment arrives, every reel and pallet of material should be inspected for damage as it is unloaded. Damaged cable should be set aside for a more detailed inspection before signing the shipping documents.

2.1 Unloading at a Dock

Methods of unloading are dependent on how the cable is delivered.

Reels are loaded on a rolling edge - Use a pallet jack or forklift to remove all cable on pallets. Remove any blocking materials for the individual rows of cable and roll the reels onto the dock.

Reels are stacked - Use a pallet jack or forklift to remove all cable on pallets. Remove any blocking materials then carefully unstack the cable and roll it off the truck.

Note: If the back of the trailer and dock are not level, use an appropriate loading ramp to compensate for the difference in heights.

2.2 Unloading Without a Dock

The cable will be unloaded using a ramp or a Cargomaster® crane.

Use of a Ramp - The ramp should be long enough to allow control of the momentum of the cable as it rolls down the ramp. The ramp should be of sufficient strength to support the weight of the unloading personnel and the heaviest cable reels. The ramp should have raised sides to prevent the cable reels from rolling off the sides of the ramp.

A pulley system connected to the sides of the truck and to a shaft passing through the center of the reels can control the momentum of the reels as the reels roll down the ramp. Two men should be able to control movement of the heaviest reel.

Use of a Cargomaster® crane - A Cargomaster® crane can unstack and move the cable to the ground at the rear of the truck.

Note: Never allow any type of cable to be rolled off the back of the truck onto the ground, onto a stack of tires, or onto any other rigid or non-rigid surface. The impact may injure personnel or damage the cable. Always use ample personnel to safely unload shipments of cable.

3.0 Unloading Fiber Optic Cable

Fiber optic cable is typically delivered on a substantially heavier reel than coaxial cable. A reel of fiber optic cable contains significantly more cable than a reel of coaxial cable. Wooden reels of fiber optic cable will be one hundred percent lagged to protect the fiber from damage during loading, transporting and unloading.

Important: All reels are marked with an arrow indicating the direction in which the reel must be rolled. All reels of fiber optic cable should be kept upright on the rolling edge, never laid flat or stacked.

Fiber optic cable is loaded and unloaded using a crane, special lift truck, or forklift due to its size and weight. Forklifts must pick the reel up perpendicular to the rolling direction. The forks must extend under the entire reel. The reel is labeled with handling directions.

The fiber optic cable should be closely examined for damage. Test results from the CommScope factory are provided with each reel.

Note: Never allow any type of cable to be rolled off the back of the truck onto the ground, onto a stack of tires, or onto any other rigid or non-rigid surface. The impact may injure personnel or damage the cable. Always use ample personnel to safely unload shipments of cable.

4.0 Filing Damage Claims

If any freight damage is visible or suspected and if it is decided to accept the shipment, notations about any freight damage must be made on the Bill of Lading.

If the damage is too extensive to accept the shipment, advise the carrier's driver that the shipment is being refused because of the damage. Immediately notify CommScope's Customer Service Department so that arrangements can be made for a replacement shipment.

Interstate Commerce Commission (I.C.C.) rules state that claims for visible damage must be filed within nine months, and claims for hidden damage must be filed within 15 days. Prompt attention is in the best interest of all parties.

When filing claims, a copy of the signed Bill of Lading must be supplied, together with a detailed damage report.

After, materials are signed for, the customer accepts liability for damage and shortages. Take the time to account for all products before signing for the shipment.

4.1 Visible Damage

Notations about visible damage must be indicated on the Bill of Lading, specifically noting the Reel Number. Make sure that any statements about damage are on both the delivery carrier's copy as well as the customer's copy.

4.2 Hidden Damage

If hidden damage is suspected, the statement "Hidden Damage - Final acceptance is subject to thorough inspection", should be written on the Bill of Lading.

Damaged freight and freight losses should be immediately reported to CommScope's Customer Service Department. The following guidelines should be followed if any product is discovered to be damaged:

Common Carrier

If the freight is accepted, the customer must file the claim with the carrier.

If the freight is refused, CommScope will file the claim with the carrier.

CommScope Carrier

If the freight is delivered on a CommScope truck, CommScope will process all claims.

5.0 Storage and Handling of Cable

Coaxial Cable

Coaxial cable can be stored indoors or outdoors, and the cable may be stacked or stored upright on the rolling edge. To stack coaxial cable, a forklift or some type of overhead hoist is needed.

When cable is stored outside, the ground should be somewhat level and have good drainage. This will reduce the possibility of deterioration of the reel flanges.

Reels which are stored upright on the rolling edge should be aligned flange to flange to prevent possible damage to the cable once the protective cover has been removed.

Fiber Optic Cable

Fiber optic cable is stored on the rolling edge and typically away from the main cable storage area. Fiber optic cable is normally given special storage as well as special security to prevent possible damage. During long term storage, fiber optic cable must be stored in a manner that protects the reel from the weather to prevent reel deterioration.

5.1 Stacking

Coaxial Cable

When coaxial cable is moved, shipped, or stored, the following table should be used to ensure that maximum stacking heights are not exceeded. Consideration must be given to the maximum height as well as the total weight of the stack. To allow the use of a pallet jack or forklift, place boards between each layer and a pallet on the ground under the bottom reel. Stacking specifications are referenced in Table 2.1.

Fiber Optic Cable

Fiber Optic Cable is never stacked. The cable is always shipped upright on the rolling edge.

5.2 Protection From Environmental Conditions

Coaxial Cable

A covering should be used to protect the packaging materials from deterioration. Plastic or canvas offers minimal protection while an open air roof provides optimum low cost protection for cable stored outside.

The same care given to new reels of cable should be provided for partial reels. Always replace cable caps and hose clamps on partial cable reels to prevent possible moisture ingress and migration of flooding compound.

Fiber Optic Cable

Fiber optic cable is normally given special storage as well as special security to prevent possible damage. Fiber optic cable must be stored in a manner that protects the reel from the weather to prevent deterioration.

Table 2.1: Cable Stacking Specifications

Product	Maximum Storage Height of Stack	Maximum Loading Height of Stack
P3 500	6 Reels	4 Reels
P3 500 Messenger	5 Reels	3 Reels
P3 625	5 Reels	3 Reels
P3 625 Messenger	5 Reels	3 Reels
P3 750	5 Reels	3 Reels
P3 875	5 Reels	3 Reels
P3 1000	4 Reels	2 Reels
QR 540	5 Reels	3 Reels
QR 540 Messenger	5 Reels	3 Reels
QR 860	5 Reels	3 Reels
QR 1125	4 Reels	2 Reels
F 59 Series	4 Cartons	3 Cartons
F 59 Messenger	6 Cartons	5 Cartons
F 6 Series	4 Cartons	3 Cartons
F 6 Messenger	6 Cartons	5 Cartons
F 7 Series	5 Cartons	5 Cartons
F 7 Messenger	5 Cartons	5 Cartons
F 11 Series	5 Cartons	5 Cartons
F 11 Messenger	5 Cartons	5 Cartons
Comm/Pak	3 Cartons	3 Cartons

Testing of CommScope Products

1.0 General

2.0 Phases of Testing

Coaxial Cable

2.1 Pre-Installation
2.2 Post-Installation and Final Acceptance

Fiber Optic Cable

2.3 Pre-Installation
2.4 Installation Splicing
2.5 Post-Installation and Final Acceptance

3.0 Testing Methods

Coaxial Cable

3.1 Attenuation
3.2 Structural Return Loss
3.3 Impedance/TDR Test

Fiber Optic Cable

3.4 Attenuation
3.4.a Backscattering (OTDR) Method
3.4.b. Insertion/Cut-Back Loss Method

4.0 Testing Cable

4.1 Test Documentation
4.2 Analysis of Test Results

1.0 General

Testing of coaxial and fiber optic cables will ensure that the performance of the cable meets the specifications of the system operator.

CommScope cables are extensively tested physically, electrically and optically prior to shipment. Precautions are taken to ensure that cables are not damaged in shipment. Fiber optic, trunk and distribution cables are sometimes tested after delivery. Drop cable is seldom tested after delivery. The intended use, quantity, specifications and ruggedness of drop cable has negated the system operators need to test drop cable.

There is not a requirement to test coaxial and fiber optic cables after delivery. Continued testing, prior to, during and after the construction process will identify any degradation in the performance of the cable caused by the construction or installation process.

2.0 Phases of Testing

There are three phases of testing for coaxial and fiber optic cables, after which testing may be used to reveal performance degradation. The phases are:

- *Pre-Installation*, this phase occurs immediately after delivery of the cable, prior to installation.
- *Installation - Splicing,* this phase occurs during splicing. Coaxial cable is not normally tested during this period.
- *Post Installation - Final Acceptance*, this phase of testing occurs after the system construction, splicing, and just prior to activation. Coaxial cable is seldom tested during this phase by methods as noted in this section except when military specifications are required.

Testing of coaxial cable after construction is accomplished as part of system activation and the Proof of Performance that may be completed as part of the system activation. Broadband frequency response testing utilizing broadband sweep equipment that allows evaluation of the entire operating spectrum of the broadband system is often included as a part of the activation process.

Coaxial Cable
2.1 Pre-Installation Testing

Pre-installation testing of coaxial cable typically consists of *Structural Return Loss (SRL)* Tests made from both ends of the coaxial cable in addition to *Impedance/Time Domain Reflectometer (TDR)* Tests also made from both ends of the coaxial cable.

Insertion Loss (Attenuation) Tests are seldom conducted after shipment of the coaxial cable from the CommScope manufacturing facility, but can be easily performed during *pre-installation* testing. Testing for attenuation by conventional testing methods is extremely difficult after installation due to the physical placement of the cable over substantial distances.

These *pre-installation* checks can provide assurances to the system operator and to the construction group about the quality of the coaxial cable prior to installation. Many times these tests are conducted jointly by the construction contractor and the system operator. This cooperation may preclude future difficulties if a cable is damaged during the construction operation.

2.2 Post Installation - Final Acceptance Testing

SRL Tests and *Impedance/TDR* Tests can be performed after installation. As noted herein, *post installation* tests are rarely performed with exception to the requirement to fulfill military specifications. If *post installation* tests are required they should be compared to the *pre-installation* test.

Fiber Optic Cable
2.3 Pre-Installation Testing

Pre-installation field testing consists of cable acceptance from the manufacturer by the system operator. The operator conducts this test with an Optical Time Domain Reflector (OTDR). The objective of *pre-installation* field testing is to assure that no damage has occurred during transit of the cable from the manufacturer to the system operator. The technicians should verify optical length, attenuation, anomalies and continuity.

This data should be recorded either electronically or with a chart recorder. The majority of cables now being specified are for dual wavelength operation. Because of the sensitivity of fiber to attenuation related difficulties at the 1550 nm wavelength, it is recommended that this *pre-installation* test be conducted at that wavelength, assuming that an OTDR with that wavelength is available.

All fibers must be checked in order for this test to be effective. Random testing can result in less than desirable assurances of the delivered product. It is easily possible for a single fiber of a multiple fiber cable to be damaged. Random testing of fibers may not reveal the damaged fiber.

These pre-installation tests can provide assurances to the system operator and to the construction group about the quality of the fiber optic cable prior to installation. Many times these tests are conducted jointly by the construction contractor and the system operator. This cooperation may preclude future difficulties if a cable is damaged during the construction operation.

2.4 Installation - Splicing Testing

Installation or splicing field tests can be performed using five basic techniques:

- Optical Time Domain Reflectometer (OTDR)
- Optical Power Monitoring
- Local Injection Detection (LID)
- Profile Alignment Systems (PAS)
- A combination of the above

There are several advantages and disadvantages to each of the approaches. Detailed documents are available for each of the techniques that the operator may use. The major points to consider are: availability of skilled technicians, equipment, and the logistics of communications during the splicing operation. In all cases, the resulting splice loss should be recorded so that this value can be used when calculating the expected system loss.

2.5 Post Installation - Final Acceptance Testing

Post Installation - Final Acceptance Testing should consist of end-to-end OTDR tests made from both directions at both 1310 and 1550 nm wavelengths. In addition, if connectors are used, an *Optical Power* Test using the *Insertion Loss* Method should be performed at both wavelengths from both directions. By performing these tests, the system operator is assured of having all the necessary data required to accurately characterize the passive optical system.

3.0 Testing Methods

The *first* and easiest test is a simple visual inspection of the cable to ensure that no obvious physical damage has occurred during shipment and unloading. After completing the physical inspection, field testing of the cable should proceed.

The testing methods for coaxial cable and fiber optic cable are as follows.

Coaxial Cable

Three tests are used to characterize the performance of coaxial cable. The tests are, the *Attenuation* Test, the *SRL* Test, and the *Impedance/TDR* Test. The tests are based on low frequency filter theory (for attenuation test), and transmission line theory (for *SRL* and *Impedance/TDR Test*).

The development of the low frequency filter theory and the applicable theory for attenuation characteristics is beyond the scope of this text. Attenuation characteristics for all CommScope cables are provided by CommScope. Any *Attenuation Test* results can be compared to the published attenuation characteristics. Attenuation characteristics of coaxial cable should not have changed from the attenuation performance as tested at the CommScope manufacturing facility. *SRL and Impedance/TDR* Tests should reveal any problems that would cause a degradation of attenuation characteristics.

Transmission line theories state that a transmission line of uniform impedance that is coupled to a transmitter and load of the same impedance, will allow all power transmitted through the transmission line to be absorbed by the load. The matching of the transmitter (source) impedance, the transmission line impedance and the load impedance defines the *impedance match.* Any variation from the *impedance match* is an *impedance mismatch.* An *impedance mismatch* in the transmission line will cause a reflection of a portion of the transmitted power dependent on the severity of the *impedance mismatch.*

Periodic discontinuities spaced at a distance that corresponds to a half wavelength of the transmitted frequency may cause additive reflections of power at the transmitted frequency and its harmonics, thus causing the reflected power to increase at the transmitted frequency.

Attenuation and structural return loss tests are performed using a wide band signal generator. It is important to note that the signal (power) is generated across a defined spectrum allowing comparison of transmitted power, received power, and reflected power, at any frequency in the defined spectrum.

Tests for *impedance mismatches* are performed using a TDR. The TDR is a time measurement device that transmits an electrical pulse down the coaxial transmission line and measures the amount of time required for the pulse to travel to an impedance mismatch and be partially reflected back to the transmit point. The TDR returns the results as a distance measurement.

Prior to testing, the cable ends must be accessed through the reel wrap and from under the stayback. All cables are shipped with cable caps that must be removed for testing. Flooding compounds should be removed prior to testing. The cable caps should be replaced onto the cable ends upon completion of testing.

Preparation of cable ends is critical in testing coaxial cable. Preparation of cable ends should be done as recommended by the connector manufacturer. Precision test connectors are highly recommended for *SRL Tests* and *Attenuation* Test.

3.1 Attenuation

Attenuation Tests measure the difference between transmitted (incident) power and received power throughout the defined spectrum. The difference is the attenuation of the cable in decibels at the measurement frequency.

In order to conduct this test, the following equipment is required:

- Wide Band Sweep Generator
- Electronic Switch
- RF Amplifier
- Detector
- Variable Reference Attenuator
- Interconnecting Cables (as required)
- Display Oscilloscope

The following procedure will assist in conducting *Attenuation* Tests:

- Configure the test equipment as indicated in **Figure 3.1.**
- Adjust the sweep range and display for the bandwidth to be tested.
- Insert a shorting jumper across the electronic switch.
- Adjust the reference attenuator to 0 dB loss and make sure that the *reference trace* and *test trace* are at the same level and coincide.
- Remove the shorting jumper from the RF switch and insert the cable under test across the RF switch.
- Use the frequency markers to identify the specific frequency at which measurements are being made.
- Adjust the variable attenuators until the *reference trace* meets the *test trace* at the frequency that is being measured.
- If more accuracy is required, increase the RF output level. The oscilloscope's vertical amplifier can be used to improve accuracy.
- The reference attenuator setting is the insertion loss (attenuation) at the frequency being tested.
- Convert the insertion loss measurement to cable attenuation by multiplying the insertion loss measurement by 100 and dividing it by the cable length. The result is the attenuation of the cable in dB per 100 feet.
- Record all test results.

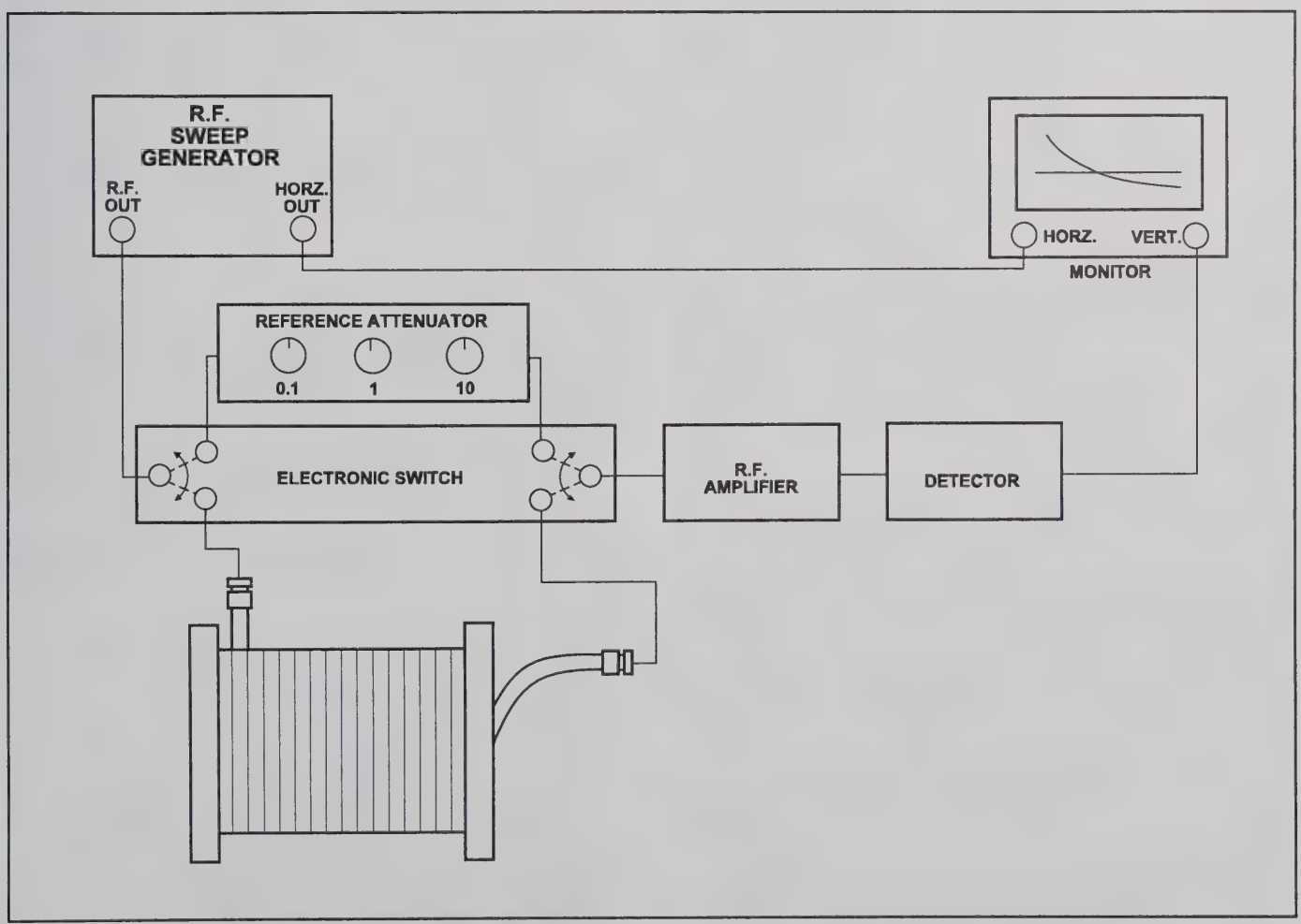


Figure 3.1: Attenuation Test Equipment Configuration

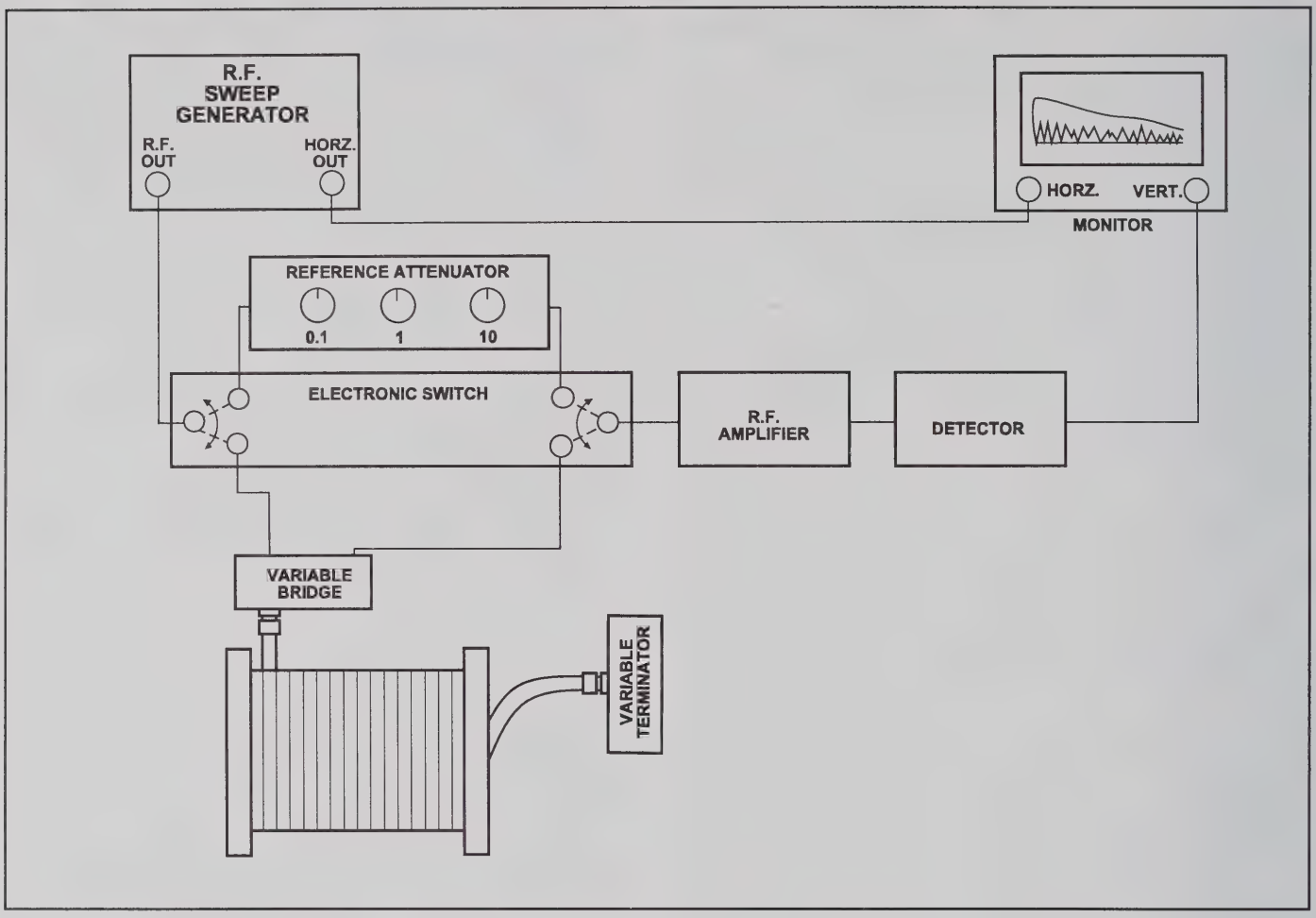


Figure 3.2: SRL Test Equipment Configuration

3.2 Structural Return Loss

SRL Tests measure incident and reflected power throughout the defined spectrum. Test results compare the incident power and the reflected power in decibels (dB). The test is essentially a measure of the ability of the cable to transfer maximum power from the transmitter to the load.

When conducting a SRL test, the impedance of the test equipment and test connectors must be matched to the impedance of the cable. To perform this task, a variable return loss bridge is required. The bridge will be adjusted so the only visible reflections are those of the cable.

In order to conduct this test, the following equipment is required:

- Wide Band Sweep Generator
- Electronic Switch
- RF amplifier
- Detector
- Variable RF Bridge
- Variable Reference Attenuator
- Variable Termination
- Interconnecting Cables (as required)
- Display Oscilloscope

The following procedure will assist in conducting SRL Tests using a variable bridge:

- Configure the test equipment as indicated in **Figure 3.2.**
- Connect the variable bridge to one end of the cable and the variable terminator to the other end.

Note: The test connector installation onto the cable is critical; errors in *SRL* Tests often result from poor connector installation.

- Adjust the sweep bandwidth and display for the bandwidth to be tested.
- Adjust the variable bridge and the variable terminator so the return loss trace is at the lowest possible baseline. The impedance of the variable return loss bridge and the variable terminator is now matched to the impedance of the cable. The maximum amount of energy can pass through the cable to the terminator with the minimal amount of reflected power being reflected by the bridge and the connectors.

- Adjust the variable attenuators until the reference trace meets the peak of the worst case return loss, which will appear as a spike on the return loss trace.
- The frequency markers can be used to identify the frequency of the worst case return loss. The sweep time and bandwidth can be adjusted narrower and slower respectively to more accurately identify the frequency and magnitude of the return loss trace.
- The worst case return loss can be read directly from the variable attenuators in dB.

Note: The loss of the bridge (typically 12 dB), if not inserted into the reference trace circuit, should be subtracted from the reading of the reference attenuator to realize the SRL results.

- The characteristic impedance can be read directly from the variable bridge.
- SRL testing should be done from each end of the cable due to the effects of attenuation. Results should be recorded for tests performed at each end of the cable.

3.3 Impedance/TDR Test

The *Impedance/TDR* Test is a quick and straight forward test. This test provides the distance from the test point to any impedance mismatch in the cable.

When using a TDR to test cable, follow the manufacturer's instructions for the TDR being used. TDR's have limitations and capabilities dependent on the model.

Impedance/TDR Tests should be made from both ends of the cable due to the effect of cable attenuation on the test results. An important note is that the velocity of propagation (VP) for the cable under test is critical. Any error in accounting for the VP will cause a proportional measurement error in the distance to the impedance mismatch. The VP is provided in the CommScope Product Catalog.

The following is the basic procedure for using a TDR:

- Set the velocity of propagation for the cable under test.
- Set the impedance reference on the TDR for 75 ohms.
- Adjust the display for a sharp, clear baseline, and position the leading edge to a convenient starting point or graticule.
- Set the pulse width as recommended by the TDR manufacturer.
- Attach the test lead (coaxial cable test leads are preferred but not always practical) to the cable under test. It is preferred to test the cable through connectors that are matched to the impedance of the cable.
- Adjust the CRT to display the entire length of the cable.

The display and control settings should be adjusted to show the entire length of the cable as well as any faults. The control settings can be adjusted to allow precise measurement of the distance to any impedance mismatch. Operator proficiency and equipment capability are critical factors in making consistent and precise measurements.

- TDR testing should be done from each end of the cable due to the effects of attenuation. Results should be recorded for tests performed at each end of the cable.

Fiber Optic Cable

Two important optical characteristics that can be measured in the field are *attenuation* and *dispersion.*

Dispersion characteristics are very closely controlled during the manufacture of the optical waveguide (glass fiber). Test equipment is extremely expensive; therefore, dispersion tests are rarely performed and generally not required in the field.

3.4 Attenuation

Attenuation measurement methods used in the field are the *back scattering method* and *two-point method.* Terms more commonly used to describe these two methods are an *Optical Time Domain Reflectometer (OTDR)* Test and the *Insertion/Cut-Back Loss* Test, respectively.

The *two-point method* is also referred to as an *Optical Power* Test. *OTDR* tests and *Insertion/Cut-Back Loss Tests* are required in order to completely and accurately characterize the overall optical condition of a fiber optic cable system.

Depending on cable and system specifications, these tests may be performed at both 1310 and 1550 nanometer wavelengths, as well as from both directions. Normally, the *Optical Power Test* is only performed as part of the *Final Acceptance Testing.* These test methods are complementary and results may vary slightly as a result of equipment, technique, and the skill of the technician performing the test. The key to successful characterization of the fiber optic cable plant is the consistent application of correct procedures. This will improve the correlation between measured and calculated optical losses.

3.4a Backscattering Method

The first and most common test method used is the backscattering method. This test is performed using an Optical Time Domain Reflectometer (OTDR). The OTDR is primarily used for locating faults, discontinuities, anomalies, and general attenuation checks.

The OTDR measures distance and loss in an optical fiber by transmitting an optical pulse through the fiber and measuring the optical power reflected back to a sensor in the OTDR.

The OTDR calculates distance along a fiber by measuring the interval between the pulse's launch and the time when the reflected energy is detected at the sensor. Loss is calculated by comparing the received power to the transmitted power. As the pulse moves along the fiber, thousands of data points corresponding to distance and relative power are gathered and displayed on the CRT. The result is a linear trace of the fiber displayed as distance from the source (horizontal axis) versus relative power (vertical axis).

The power reflected from the fiber is caused mainly by Rayleigh scattering. This occurs when light traveling in a fiber strikes a non-uniform part of the core's molecular structure or a non-silicon dioxide particle, and is then scattered in a spherical pattern. The part of the scattered optical energy which travels back toward the optical source is called the "backscatter" and is the basis for the OTDR measurements. Every fiber has a unique "backscatter coefficient." This is a measure of how well optical energy is reflected back to the source. The backscatter coefficient depends on the fibers relative refractive index difference (the difference between the indices in core and cladding), the core refractive index, and the core diameter.

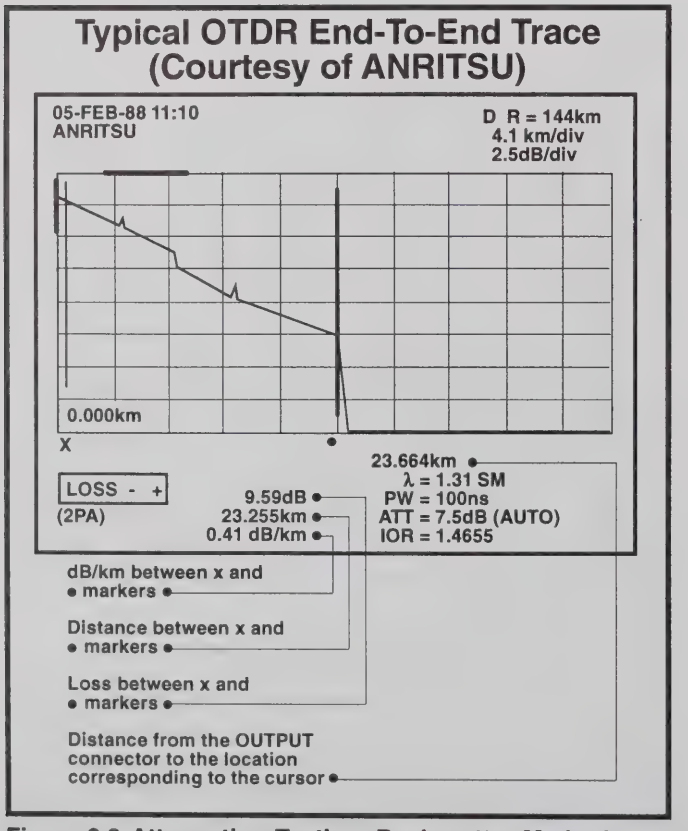


Figure 3.3 Attenuation Testing, Backscatter Method

General attenuation checks include cable reel acceptance, splice loss verification, and final end-to-end measurements. Signature traces should be made of all fibers after connectors are installed, thereby depicting the entire cable route. See Figure 3.3 Attenuation Testing, Backscatter Method. The traces will be invaluable if trouble develops on the passive cable plant. Most important, the OTDR is essential for locating faults in the outside plant cable.

The OTDR has several significant advantages over other test methods. It is an extremely versatile instrument that can be operated by the technician with a minimal amount of training. It is the optical device normally used to locate fiber discontinuities in the cable plant. Through periodic comparison with the initial signature traces, the OTDR may provide early warning of a potential catastrophic failure by indicating points of stress in the cable.

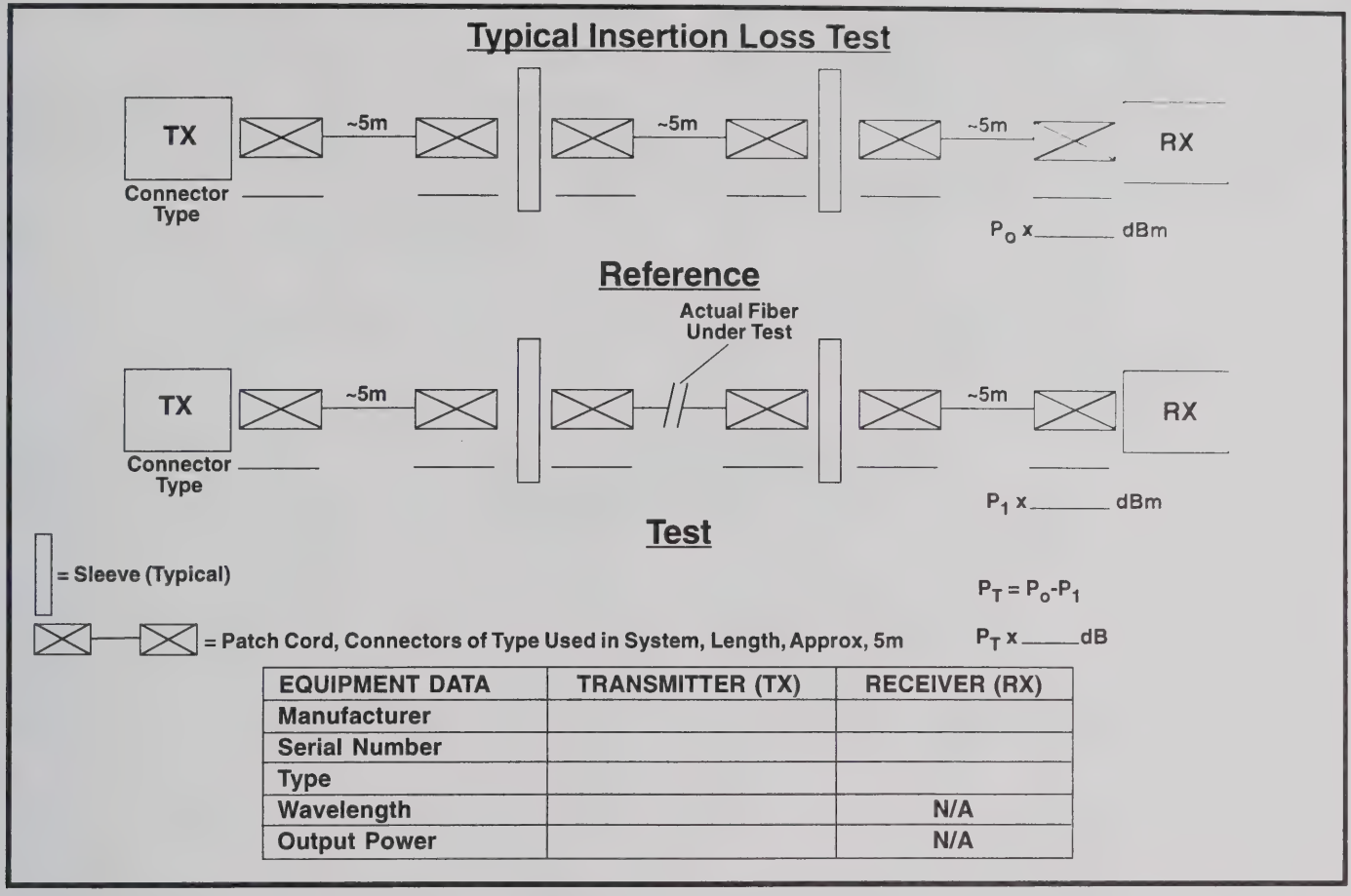
Although the OTDR is a very accurate and important test instrument, several inherent factors make the OTDR the least accurate of the attenuation methods that may be employed in the field. For extremely precise attenuation measurements, the *cutback* or *insertion loss* method should be used.

3.4b Insertion/Cut-Back Loss Method

By definition, the *cut-back method* is a destructive test and is not normally used for a fully concatenated fiber optic cable system. It is not commonly seen in the field, but because of its accuracy and precision it is often specified and used in cable manufacturing for acceptance testing. This method is seldom used in the field because of its destructive nature.

The *insertion loss test* method is very similar to the *cut-back* method. It is also called the *Attenuation by Substitution* Method. This test method is defined in EIA standard, EIA-455-171, *Attenuation by Substitution Measurement - for Short Length Multimode Graded Index and Single-Mode Optical Fiber Cable Assemblies.* The equipment required to perform this test includes a stabilized light source (normally a laser), an optical power meter or receiver, and various patch cords or jumpers with connector sleeves used to emulate and access the fiber cable system.

With this method, the first step is to establish a "reference" value to characterize the transmitter, receiver and connector assemblies. This consists of inserting a short reference cable between the transmitter and receiver of the attenuation measuring *(optical power meter test)* set and measuring the transmitter output power P_o coupled into the fiber jumper assembly. In the second step, the reference cable is replaced by the cable link to be measured and inserted attenua-



EQUIPMENT DATA	TRANSMITTER (TX)	RECEIVER (RX)
Manufacturer		
Serial Number		
Type		
Wavelength		N/A
Output Power		N/A

Figure 3.4 Attenuation Testing, Insertion Loss Method

tion is obtained by comparing the level available at the output side of the cable link P_i with the reference level P_o. Figure 3.4 is a depiction of a Fiber Optic Insertion Loss Test.

The *Insertion/Cut-Back Loss* method has the advantage in that it is simple to perform and can be used for fully connectorized/concatenated cables. However, this method has one disadvantage in that the varying coupling conditions on the transmitter or receiver side may cause the reference level to deviate from the level coupled into the cable link, thereby resulting in minor measuring errors.

4.0 Testing Cable

Coaxial Cable

Test results for coaxial cable result in pass/fail results for the cable in the *pre-installation* testing. System operators require a specific level of performance and any cables failing to meet the performance standards are not used in the system. Performance of the coaxial cable cannot fully ensure the performance of the coaxial cable system. Testing of the cable will ensure the cable's performance contribution to the overall system performance.

Fiber Optic Cable

Fiber optic test results relate the performance of the optical system. Documentation is more critical than that suggested for coaxial cable because there are many fibers in one cable, the lengths of cable installed are significantly longer, and replacement costs can be extremely high.

4.1 Test Documentation

Coaxial Cable

Chart recordings and magnetic recordings of cable performance across the defined spectrum are beneficial, especially in the event of an expansion of the operating bandwidth of the plant. These results are of little benefit in evaluation of the performance of the plant on a cable by cable basis.

Coaxial cable is cut into many individual lengths each separated by equipment. *SRL Tests* and *Attenuation Tests* are impractical as a *post-installation* test and provide little usable information after the cable has been cut between splice locations. Recording the *reel number* of the cable and the location of installation will enable evaluation of the manufacturing and testing that is specific to that reel of cable at any point in the future.

End-to-End *Impedance/TDR* Tests are of the highest benefit in an evaluation of *post-installation* plant performance. The following documentation should accompany all test results if future analysis of cable performance in the field is desired:

- As-built Drawings, with reel numbers of the installed cable
- End-to-End TDR Signature Traces

Fiber Optic Cable

The *minimum* documentation required for a fiber optic cable system should include the following:

- As-Built Drawings
- Splice Loss
- End-to-End Optical Loss Measurements
- End-to-End OTDR Signature Traces

The purpose of this data is to provide historical references for maintenance and emergency restoration. By maintaining this data, the system operator is assured of a prompt response by the quick identification, location and repair of any problem that may occur within the passive cable plant.

4.2 Analysis of Test Results

Coaxial Cable

Test documentation for coaxial cable results in a pass/fail rating; however, long term documentation will allow future analysis of the performance of the cable in the field.

Fiber Optic Cable

The data that has been acquired during the testing of the fiber optic cable is then analyzed. This measured field data is compared to the data that was obtained by summing cable loss, splice loss and pigtail loss. It is not unusual to see variations on the order of +/-5% between the results calculated or measured from these multiple tests. Values outside of these ranges should be investigated. These differences can be caused by any or all of the following:

- Optical Loss Calculation Methods
- Physical Layout of Pigtails in Fiber Distribution Panels
- Testing Procedures
- Cleaning Procedures
- Condition of Connectors
- Differences in Test Equipment

The values derived from the OTDR test and the Insertion Loss test are complementary. The OTDR provides an overall "picture" of the condition of the installed fiber optic cable system. The *Insertion Loss* Test provides an absolute value of optical power through all connectors, sleeves, splices and fiber.

Three sets of field data should be collected during the installation process in order to maintain complete records about the optical properties of the passive cable system. This data is as follows:

- Calculated Data – Obtained from Cable Reel Data Sheets and Splicing Logs
- OTDR Data-Obtained from end-to-end cable test
- Insertion Loss Data-Obtained from end-to-end cable test

This data becomes part of the permanent record for both the customer's and the cable manufacturer's files. It is essential that any operator of a fiber transmission system maintain adequate information about that system for maintenance, trouble-shooting and emergency restoration procedures. Information required to maintain that system includes results from Optical Time Domain Reflector (OTDR) and Optical Power tests. The two measured and one calculated tests provide complementary information that accurately and completely characterize the optical condition of the passive fiber cable plant.

By periodically verifying the attenuation loss of the cable system with either an OTDR or Optical Attenuation Test Set, the cable operator may be able to preclude future difficulties with the transmission medium. The objective is to ensure by field testing that the installation of the passive cable plant was completed at the same high levels of quality as both the manufacturing and cabling operations.

Safety

1.0 General
- 1.1 Grades of Construction
- 1.2 Regulation and Code Availability

2.0 OSHA Regulations
- 2.1 Purpose of Section 1910.268
- 2.2 Scope of Section 1910.268

3.0 National Electric Safety Code
- 3.1 Purpose of the NESC
- 3.2 Scope of the NESC

4.0 National Electric Code
- 4.1 Purpose of the NEC
- 4.2 Scope of the NEC

5.0 Pole Lease Agreements

6.0 Local, Municipal, and State Codes

7.0 Governing Code or Regulation

1.0 General

Construction of a broadband cable system requires a substantial amount of manpower, tools and equipment. Underground and aerial construction will expose the manpower, tools and equipment to hazards, dependent on the conditions and circumstances that exist in the field.

Experience in hazard recognition and sound judgement in hazard avoidance is required from all construction personnel to prevent harm to the construction crew, general public, cable plant, and other utilities. The Occupational Safety and Health Administration (OSHA) defines a *qualified employee* as "any worker who by reason of training and experience has demonstrated his ability to safely perform his duties." Only a *qualified employee* should be assigned duties that could cause harm or potential harm to the aforementioned people and facilities

This manual cannot identify the many hazards exist in the construction environment, nor can it dictate the caution required with all of the tools, equipment and field conditions. CommScope continues this manual with the assumption that the construction personnel performing the work are *qualified employees.*

Three sets of national codes and standards that are applicable in the construction of cable systems. Section 1910.268 of the OSHA Safety and Health Standards applies to work in telecommunications centers and the telecommunications field installations. The National Electric Safety Code (NESC), generally applies to outside plant construction. The National Electric Code (NEC) applies to building utilization wiring, i.e., inside plant construction. The NEC applies specifically to but not limited to plant that is within or on public and private buildings or other structures.

Municipal, state, county, and local codes are often made applicable to the construction of cable systems or work that involves their respective properties and right-of-ways. *Pole Lease Agreements* often stipulate specific practices related to safety.

These codes, regulations, and specified practices should be investigated, interpreted, communicated and observed.

1.1 Grades of Construction

The NESC defines grades of construction on the basis of strength requirements for reasons of safety. Section 24 of the NESC identifies construction grades B, C, D and N. Grade B is the highest grade followed by C, D and N. Grade D construction typically applies to communication system lines including broadband coaxial cable and fiber optic cable. Construction grades B or C may be applicable dependent on the situations that exist. If more than one grade of construction applies to a situation, the higher grade will apply. A qualified engineer should evaluate required construction and dictate the grade of construction. The strength requirements for the various grades of construction are defined with in Section 26 of the NESC.

1.2 Regulation and Code Availability

OSHA standards can be obtained from the:

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

Phone: (202) 783-3238

The generally applicable OSHA standards are found in:

a. Title 29 CFR Parts 1901.1 to 1910.441 General Industry, (OSHA), Order No. 869-019-00111-5

b. Excavations (OSHA 2226), Order No. 029-016-00125-5

c. Underground Construction (Tunneling) (OSHA 3115)

d. Stairways and Ladders (OSHA 3124)

The NESC can be obtained from the:

IEEE Service Center
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331

Phone: (800) 678-4333

The NEC Handbook can be obtained from the:

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9146
Quincy, MA 02269-3555

Phone: (800) 344-3555

2.0 OSHA Standards Section 1910.268

OSHA Standards were established in 1970 to help ensure workplace safety. The Standards are federal regulations that are intended to enable employers and employees to recognize, understand, and control hazards in the workplace. Standards have been established for general industry while some sections of the Standards are dedicated to specific industries such as telecommunications.

Regional OSHA offices are identified in **Appendix A.**

An outline of the OSHA standards for telecommunications, Section 1910.286 Telecommunications, can be found in **Appendix B.** It must be noted that this sec-

tion is not all inclusive of the OSHA standards that apply to cable systems.

2.1 Purpose of Section 1910.268

The purpose of OSHA standards Section 1910.268 Telecommunications is noted in the Section as follows:

"This section sets forth safety and health standards that apply to the work conditions, practices, means, methods, operations, installations, and processes performed at telecommunications *centers* and telecommunications *field* installations, which are located outdoors or in building spaces used for such field installations."

2.2 Scope of Section 1910.268

The scope is identified in Section 1910.268 as a continued definition of telecommunication "center" and telecommunications "field" installation:

"Center" work includes the installation, operation, maintenance, rearrangement and removal of communications equipment in telecommunications switching centers. "Field" work includes the installation, operation, maintenance, rearrangement and removal of conductors and other equipment used for signal or communication service, and of their supporting or containing structures, overhead or underground, on public or private rights-of-way, including buildings or other structures."

3.0 National Electric Safety Code (NESC)

The NESC typically identifies the construction techniques and materials necessary in outside plant construction of electric supply or communication cable systems. The NESC is an American National Standard that has been written by a group of professionals that are concerned about the Standard's scope and provisions. The NESC has been adopted by the American National Standards Institute (ANSI).

All references to the NESC in this manual are from the 1993 edition.

Special attention should be given to NESC **Table 232-1, Vertical Clearance of Wires, Conductors, and Cables Above Ground, Roadway, Rail, or Water Surfaces** which is in part reproduced in **Table 4.1.**

Table 4.1: Vertical Clearance of Wires, Conductors, and Cables Above Ground, Roadway, Rail or Water Surfaces

Nature of surface underneath wire, conductors or cables	Noninsulated communication conductors, supply cables or 0 to 750 V meeting Rules 230C2 or 230C3
1. Track rails of railroads (except electrified railroads using overhead trolley conductors)	24.0 feet
2. Roads, streets, and other areas subject to truck traffic	16.0 feet
3. Driveways, parking lots, and alleys	16.0 feet
4. Other land traversed byt vehicles, such as cultivated, grazing, forest, orchard, etc.	16.0 feet
5. Spaces and ways subject to pedestrians or restricted traffic only	12.0 feet
6. Water areas not suitable for sailboating or where sailboating is prohibited	14.5 feet
7. Water areas suitable for sailboating, including lakes, ponds, resevoirs, tidal waters, rivers, streams, and canals with an unobstructed surface area of:	14.5 feet
a. Less than 20 acres	18.0 feet
b. Over 20 to 200 acres	26.0 feet
c. Over 200 to 2000 acres	32.0 feet
d. Over 2000 acres	38.0 feet
8. Public or private land water areas posted for rigging or launching sailboats	Clearance above ground shall be 5 feet greater than in 7 above, for the type of water areas served by the launching site.

3.1 Purpose of the NESC

The purpose of the NESC (1993) is identified in Section 1 of the NESC as follows:

"The purpose of these rules is the practical safeguarding of persons during the installation, operation or maintenance of electric supply and communication lines and associated equipment."

"These rules contain the basic provisions that are considered necessary for the safety of employees and the public under the specified conditions. This code is not intended as a design specification or as an instruction manual."

3.2 Scope of the NESC

The scope of the NESC (1993) is also identified in Section 1 of the NESC as follows:

"These rules cover supply and communication lines, equipment, and associated work practices employed by a public or private electric supply, communications, railway, or similar utility in the exercise of its function as a utility. They cover similar systems under the control of qualified persons, such as those associated with an industrial complex or utility interactive system."

"NESC rules do not cover installations in mines, ships, railway rolling equipment, aircraft or automotive equipment, or utilization wiring except as covered in Parts 1 and 3. For building utilization wiring requirements, see the National Electrical Code, ANSI/NFPA 70-1990 [47]."

4.0 National Electric Code (NEC)

The NEC typically identifies the construction techniques and materials necessary in building wiring requirements, i.e., inside plant construction, of fiber optic or coaxial cable systems. The NEC has been developed by the National Fire Protection Association's (NFPA's) National Electric Code committee. Committee members are professionals from the electrical industry. The NEC addresses safety from fire and electrocution. The NEC has been adopted by the American National Standards Institute (ANSI).

4.1 Purpose of the NEC

The purpose of the NEC (1993) is identified in Article 90-1 of the NEC as follows:

"The purpose of this Code (NEC) is the practical safeguarding of persons and property from hazards arising from the use of electricity."

4.2 Scope of the NEC

The scope of the NEC (1993) is identified in Article 90-2 of the NEC, and covers:

"Installations of electrical conductors within or on public or private buildings or other structures, including mobile homes, recreational buildings and floating buildings; and other premises such as yards, carnival, parking, and other lots, and industrial substations."

"Installations and conductors that connect to the supply of electricity."

"Installations of other outside conductors and equipment on the premises."

"Installations of optical fiber cable."

5.0 Pole Lease Agreements

Cable system operators often enter into contractual agreements with the owners of utility poles. The pole owners are municipalities, telephone companies, and power companies. There are often specific safety practices that are specified in the contract. These safety practices may be more restrictive than other codes and standards. The contractual agreements should be investigated for safety requirements. The requirements should be interpreted, communicated and accordingly observed.

6.0 State, Local, and Municipal Codes

State, local and municipal codes may also apply to the construction of the cable system. These codes will vary by location. These codes will have to be identified and applied as required on a location specific basis.

7.0 Governing Code or Regulation

The more restrictive code or regulation must always be practiced.

Tools and Equipment

1.0 General

2.0 Aerial Construction Tools

3.0 Subsurface Construction Tools

4.0 Tools and Equipment Common to Aerial and Subsurface Construction

5.0 Splicing Tools

5.1 Coaxial Cable Splicing Tools

5.2 Fiber Optic Cable Splicing Tools

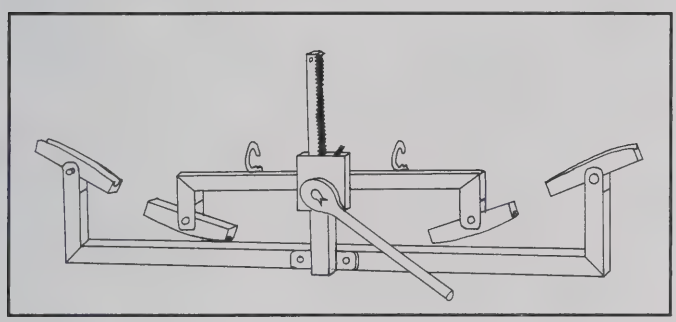
1.0 General

The purpose of this section of the CommScope Construction Manual is to introduce some of the tools and equipment that are used in the construction methods discussed throughout the remainder of this manual. Not all tools and equipment used in the construction of broadband and CATV plant will be presented in this section. Specialized tools specific to coaxial and fiber optic cable construction will be presented. This section is not intended to be a users guide for the tools. The personnel using the tools and equipment should be thoroughly familiar with the operation and possible hazards in the use of the tools and equipment.

2.0 Aerial Construction Tools

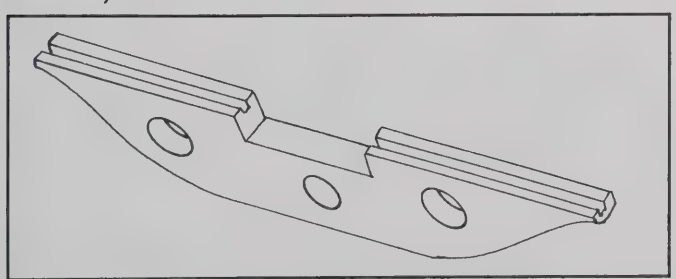
The following tools are used in coaxial and/or fiber optic cable aerial construction.

Bender, Mechanical



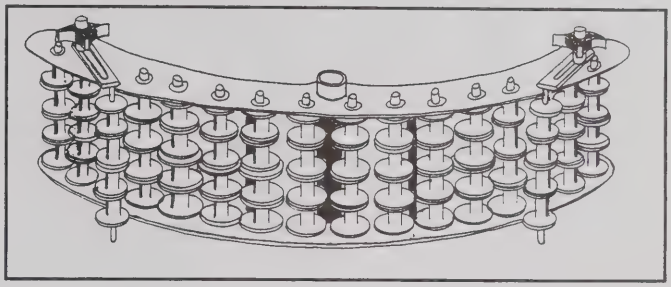
This tool is used to bend *expansion loops* into coaxial cable. This tool uses a mechanical wrenching action to bend the *expansion loop* into the cable prior to lashing or during splicing. Some *mechanical benders* are adjustable to provide for some variation in loop size. *Mechanical benders* are somewhat specific to cable diameters. The *expansion loops* formed by this tool should be compatible with the *expansion loops* made by the *bender board* identified in this section.

Bender, Board



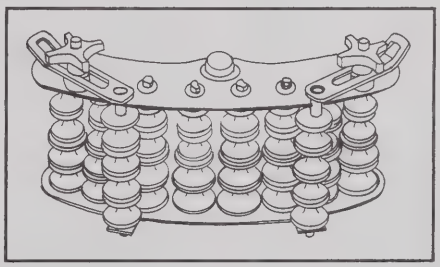
This tool is used to bend *expansion loops* into coaxial cable. The *bender board* is made from wood or molded plastic. Craftsman will form the coaxial cable around the *bender board* prior to lashing the cable or during splicing. *Bender boards* are somewhat specific to cable diameters. Bender boards are generally available in two sizes. The *expansion loops* made by this tool should be compatible with the *expansion loops* made by the *mechanical benders* identified in this section.

Block, (90 Degree) Corner



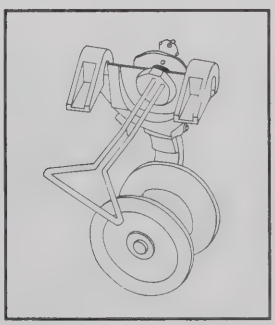
This equipment is used to route cables through inside or outside corners up to 90 degrees. This equipment should ensure that minimal drag is placed on the cable due to the corners and also ensure that the minimum bend radius of the cable is not exceeded. This equipment requires specialized mounting hardware dependent on the specific use of the equipment.

Block, (45 Degree) Corner



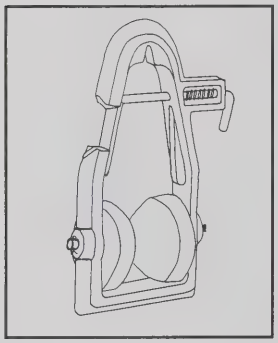
This equipment is used to pull cables through inside or side corners up to 45 degrees. This equipment should ensure that minimal drag is placed on the cable due to the corners and also ensure that the minimum bend radius of the cable is not exceeded. This block may be used as a *set-up chute*. The *corner block* is used to guide cables from the *cable trailer* or a *reel stand* when used as a *set-up chute*. This equipment requires specialized mounting hardware dependent on the specific use of the equipment.

Block, Single Roller

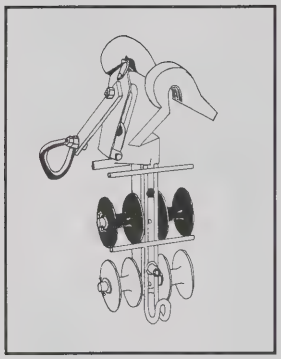


This block is typically used to support a single cable prior to lashing. This block may be used when cables are lashed directly to strand or in overlash applications. In new strand situations, *single roller blocks* may be locked onto the strand. In overlash applications, this block should not be pushed in front of

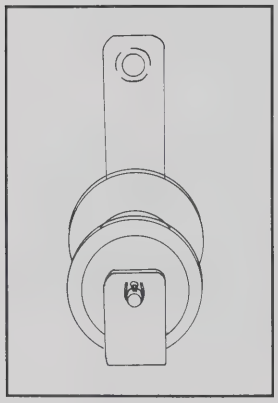
the lasher. Multiple small cables can be supported within the *single roller block* although cable positioning prior to lashing is a concern.



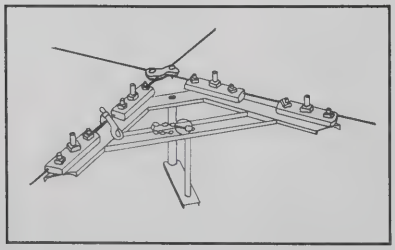
Block, Economy
This inexpensive block is used to support a single cable prior to lashing. This block may be used when cables are lashed directly to strand or in overlash applications depending on the specific block used.



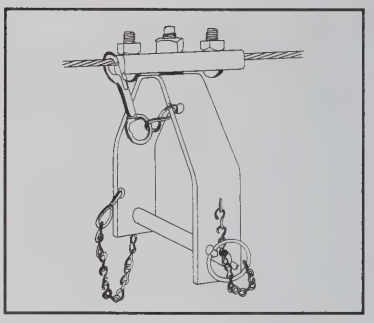
Block, Multiple Cable
This block is used to support multiple cables in independent rollers. *Multiple cable blocks* make a *cable positioner* unnecessary when lashing multiple cables.



Block, Pole Mount Cable
This block is used to install self-support cable. It is attached to the pole hardware to support the self-support cable as the cable is pulled out.

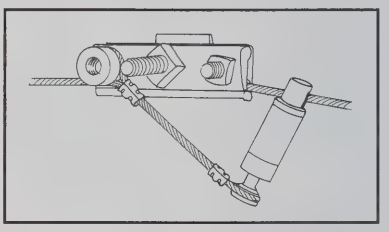


Bracket, Crossover
This bracket is used to support *corner blocks* at aerial crossovers.



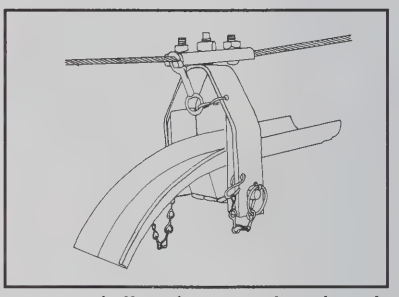
Bracket, Set-Up
This bracket is used to support a 45 degree *corner block* or a *set-up chute* mid-span.

Brake, Strand



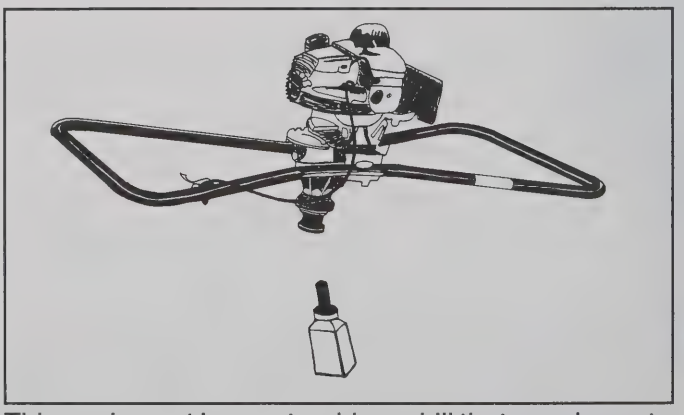
This device is selectively placed at pole hardware locations to prevent dangerous strand sag while strand is being installed. The *strand brake* allows the strand that is being pulled into place to move in only one direction, which is the direction of the strand pull. Use of *strand brakes* in conjunction with *reel brakes* effectively limits the amounts of strand sag between poles during strand installation.

Chute, Set-Up

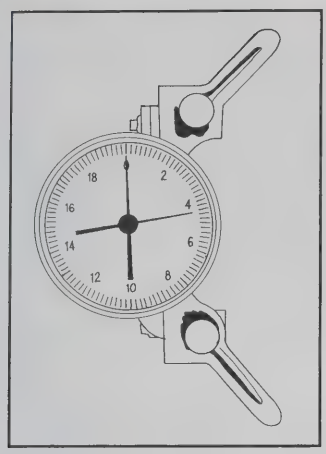


A *set-up chute* is used to guide cables from the *cable trailer* or *reel stand*. The *cable trailer* or *reel stand* should be in line with the strand, otherwise a 45 degree *corner block* should be used for this purpose. This equipment requires specialized mounting hardware dependent on the specific use of the equipment.

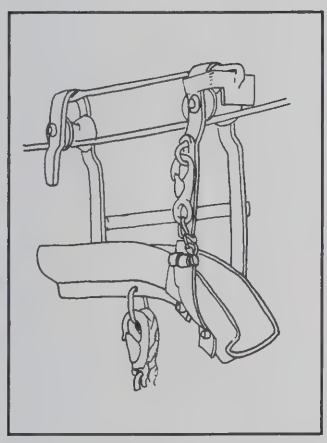
Driver, Anchor Rod



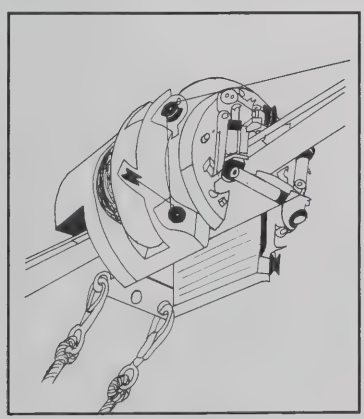
This equipment is a motor driven drill that couples onto an anchor rod to directly drill the anchor rod into the earth.



Dynamometer
A dynamometer is used to measure the pulling tension applied to cables.



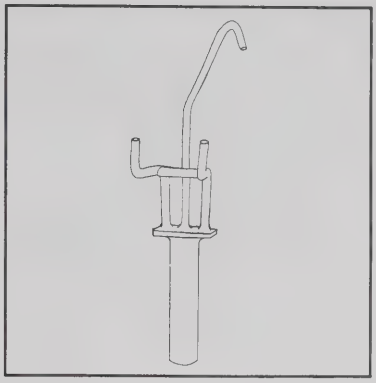
Guide, Cable
This equipment is used to guide the cable into the lasher in drive-off applications. *Cable guides* can be used during installation of cables directly to new strand or in overlash applications. The *guide* may be pushed in front of the *lasher* with a *cable block pusher*, pulled in front of the *lasher* or physically attached to the *lasher,* dependent on the *cable guide* type.



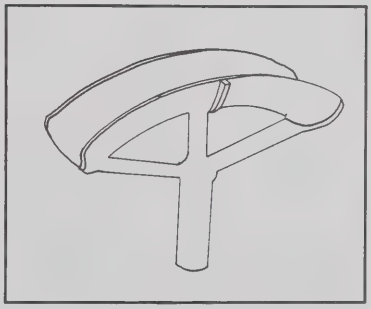
Lasher, Cable
This equipment is used to lash cable directly to installed strand or cable bundles. *Lashers* are somewhat specific to cable and strand size. Improper *lasher* size or adjustment may damage cables.

Lay-up Stick
This equipment consist of sections of fiberglass poles with interconnection hardware to facilitate the connection of the various sections to for a longer pole. *Lay-up sticks* are used to lift *cable blocks* and cables into place utilizing appropriate *lay-up stick heads*.

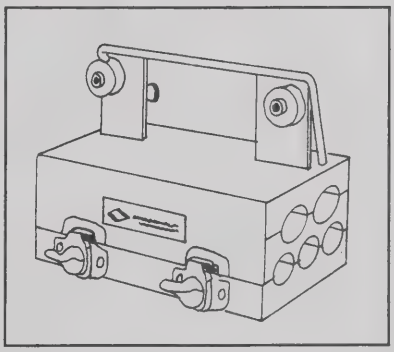
Lifter, Cable Block
This tool is a *lay-up stick head* that is used in conjunction with a *lay-up stick* to place assorted *cable blocks* mid-span.



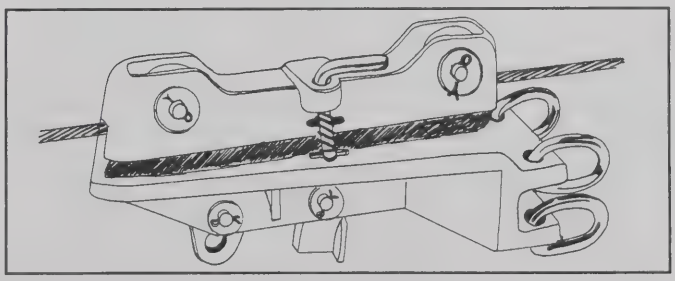
Lifter, Cable
This tool is a *lay-up stick head* that is used in conjunction with a *lay-up stick* to lift cables into place. The lifter ensures that the cables that are lifted are not damaged by micro-bending or by exceeding minimum bend radii.

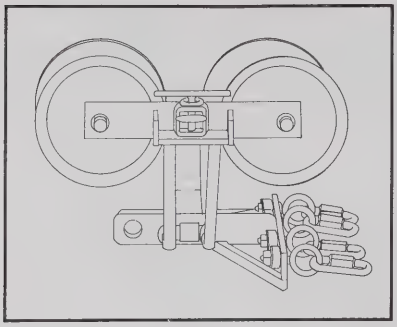


Positioner, Cable
This device is pushed in front of a *lasher* by a *cable block pusher* to uniformly position multiple cables that are being lashed. A cable positioner is also referred to as a *magic box*.



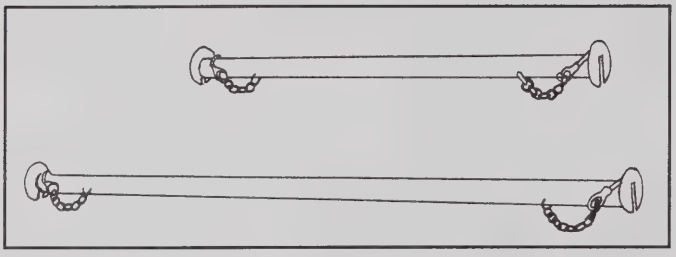
Puller, Multiple Cable
This device allows multiple cables to be pulled into place when lashing cables directly to strand. The *multiple cable puller* is equipped with a strand brake to prevent sagging of cables as the pulling tension is released. Swivels allow the cables that are being pulled to independently swivel.



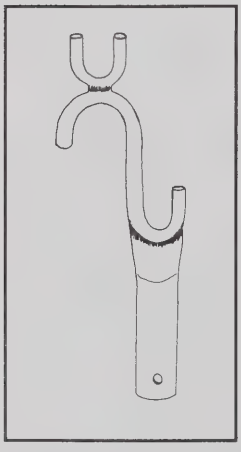


Puller, Overlash Cable
This device allows multiple cables to be pulled into place in overlash applications. Swivels allow the cables that are being pulled to independently swivel.

Pusher, Cable Block



This device is used to push equipment ahead of a pulled *lasher*. A *cable block pusher* is also referred to as a *shotgun* or *shuttle.*

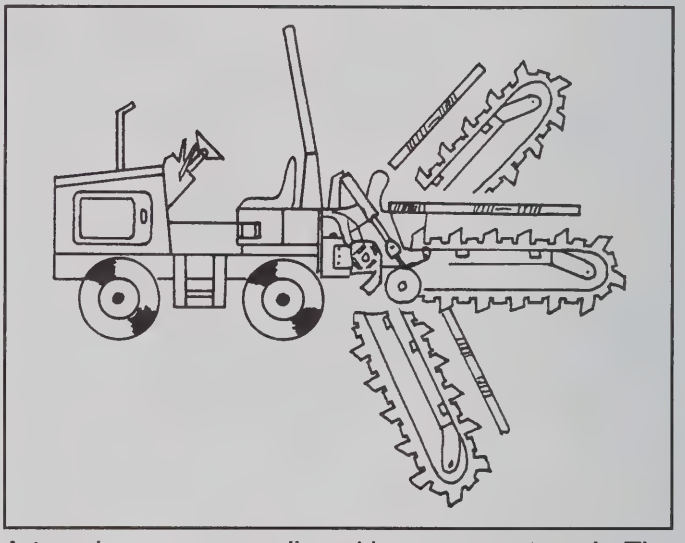


Raising Tool, Wire
This tool is used to lift *cable blocks* and strand. The *wire raising tool* may also be cautiously used to lift cables into place.

3.0 Subsurface Construction Tools

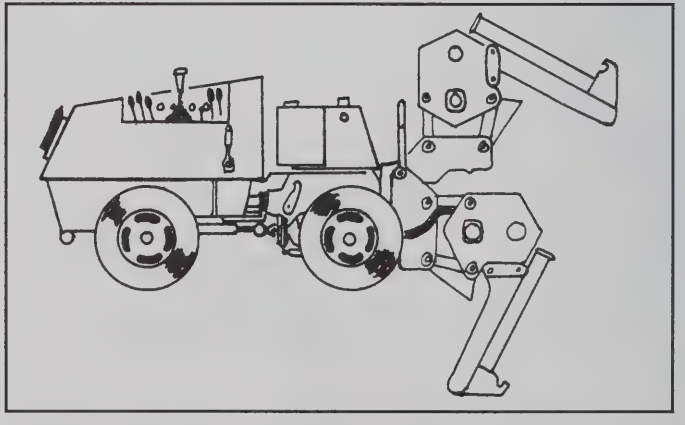
Underground construction tools and equipment consist primarily of mechanized equipment. Mechanized equipment will excavate the ground or directly bury the cable or its duct. The cable is placed into conduits that have been installed in the ground or directly buried in the ground. The following tools and equipment are used in fiber optic and coaxial cable construction.

Trencher



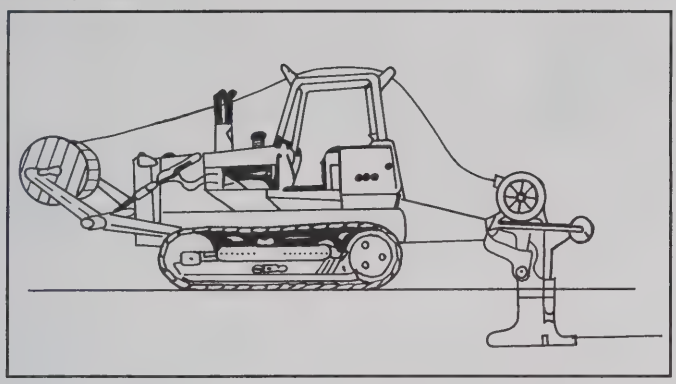
A *trencher* removes soil, making an open trench. The soil removed, i.e., spoil, is placed adjacent to the trench. The *trencher* may be equipped with a blade to facilitate the pushing of the spoil back into the trench after the cable or duct has been installed.

Plow, Vibratory

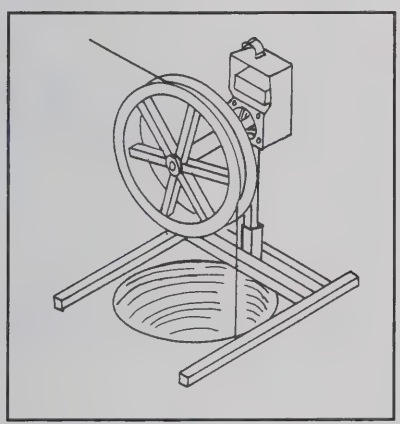


Vibratory plows use a vibrating blade to split the ground. The cable or duct is routed down through the vibrating blade and placed at the bottom of the split made by the vibrating plow blade. A *plow tractor* carries the plow and provides forward movement for the plow. The cable can often be transported by the plow tractor.

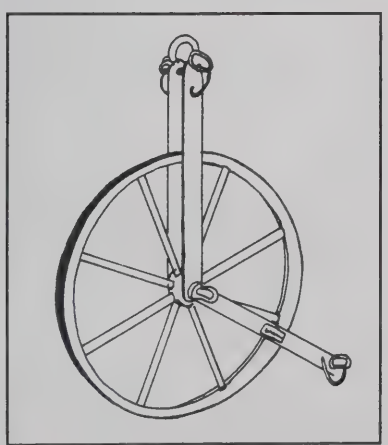
Plow, Static



Static plows split the ground by forward movement of the plow tractor. The cable or duct is routed down through the *static plow* blade and is placed at the bottom of the split made by the plow blade. A *plow tractor* carries the plow and provides forward movement for the plow. The cable is often transported by the *plow tractor.*

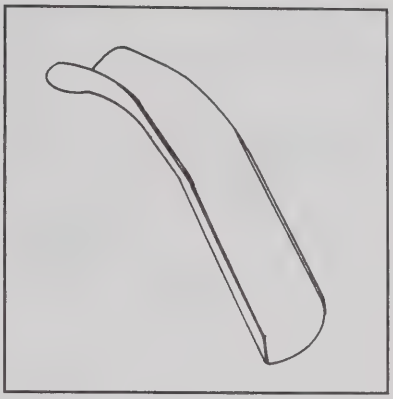


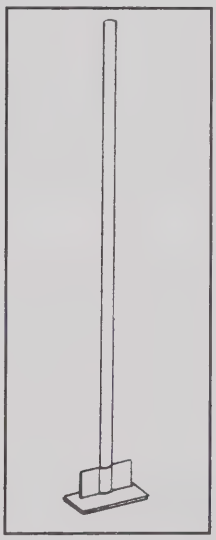
Winch, Cable
A *cable winch* is a powered capstan used to pull cable. This equipment will often be used as an intermediate assist in pulling cables that are very long or have considerable drag.



Sheave, Cable
This equipment is used to facilitate the movement of cable that is being pulled into place through a manhole. *Cable sheaves* are free wheeling and accordingly add little drag to the cable that is being installed. The placement of the sheave will prevent the rubbing of the cable on obstacles within the manhole.

Shoe, Cable
This equipment is used to route cable through manholes while the cable is being pulled into place. Placement of the *cable shoes* will prevent the rubbing of the cable on obstacles within the manhole.

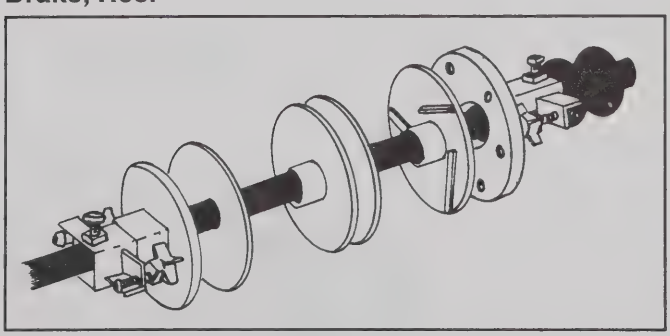




Tamper, Trench
This equipment is a specialized tool that allows compaction of back-fill soil. The trench tamper typically has a weighted tamping head and long handle.

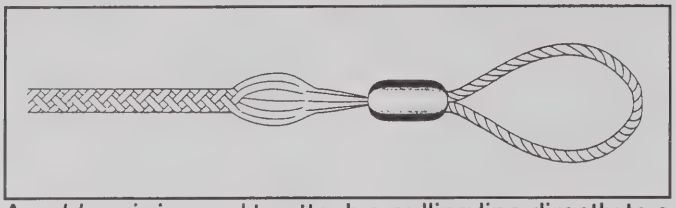
4.0 Tools and Equipment Common to Aerial and Subsurface Construction

Brake, Reel



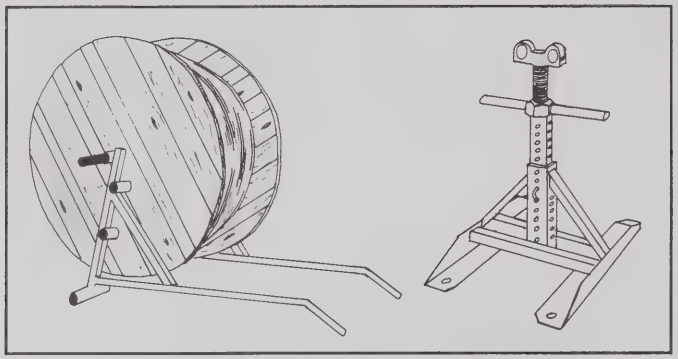
This equipment is used on a *cable trailer* arbor to prevent uneven cable payout and possible cable kinking or microbending. Sag in cable being pulled into place can be controlled by proper braking.

Grip, Cable



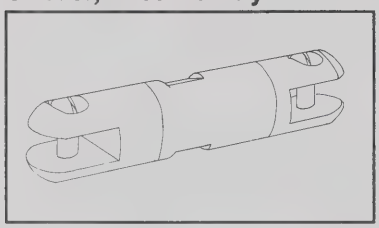
A *cable grip* is used to attach a pulling line directly to a cable. *Cable grips* are specific to cable size.

Reel Stands



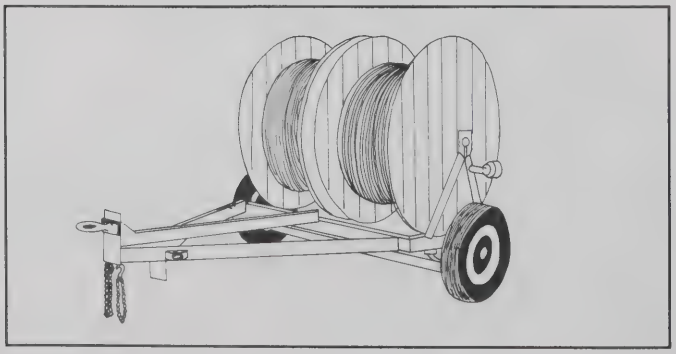
Reel stands are used to support cable reels to allow cable payout. The *reel stand* is preferred in locations not accessible to *cable trailers. Reel stands* are also referred to as *reel bucks.*

Swivel, Break-away



Break-away swivels allow cables that are being pulled to swivel and are used to ensure that the cables are not overtensioned during pulling. The *swivel* will unlink, i.e., yield, when a specified pulling tension is exceeded. *Break-away swivels* are manufactured in a variety of yield strengths. The *swivels* are used in pulling cables in underground and aerial applications.

Trailer, Cable



This equipment is used to move cable reels to the location of cable installation. The *cable trailer* is pulled by a vehicle. The cable reel is supported on the *cable trailer* by a reel arbor that is passed through the center hole of the cable reel. Cable can payout directly from the trailer. *Reel brakes* that are placed on the reel arbor can be adjusted to control the payout of cable from the *cable trailer. Cable trailers* can typically be loaded without the use of mechanized equipment.

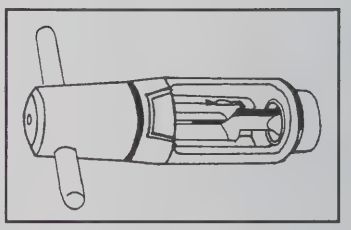
5.0 Splicing Tools

Splicing tools are specialized tools that allow the joining of cables to equipment or to other cables. Coaxial cables have connectors that are specific to each size and type of cable. Fiber optic cables are spliced by using mechanical connectors or by directly fusing the fibers together.

5.1 Coaxial Cable Splicing Tools

Coring Tools

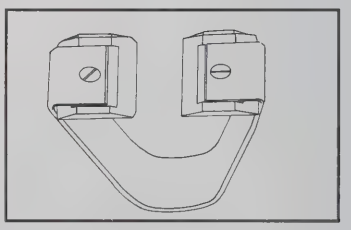
Coring tools are used to remove the dielectric from the coaxial cable to the depth required by the specific connector being installed.



Outer Conductor Cutting Tool

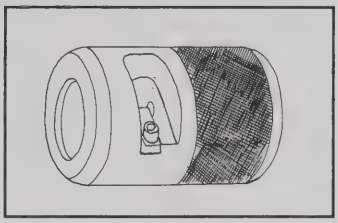
These tools remove only the aluminum outer conductor of the cable. The dielectric is exposed after the outer conductor is removed.

Center Conductor Cleaner



Center conductor cleaners are used to scrape the dielectric remnants from the center conductor after the dielectric has been removed by other means. These devices should be manufactured from a material that will not mar the center conductor. A piece of plexiglass is often used as a *center conductor cleaner.*

Jacket Cutting Tool



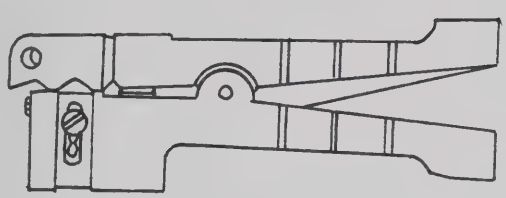
Jacket cutting tools are used to remove the outer polyethylene jacket from the cable. Use of *jacket cutting tools* is preferred over the use of a knife to remove the jacket due to the tendency of the knife to score the aluminum outer conductor.

Preparation Tools

Preparation tools perform several splicing steps simultaneously. These tools cut the outer conductor and center conductor to length while coring the dielectric from the cable to the proper depth. Removal of the dielectric remnants from the center conductor and cutting the jacket to length must be subsequently done with other tools.

5.2 Fiber Optic Cable Splicing Tools

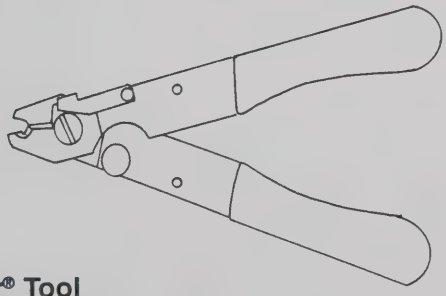
Buffer Tube Cutter - Typical



Ideal® Buffer Tube Cutter

Buffer tube cutters are used to score the buffer tubes. The tubes are removed in sections from the fiber optic cable, exposing fibers for splicing. Most buffer tube cutters can be used on 3mm loose tube buffer tubes and 8mm central core buffer tubes.

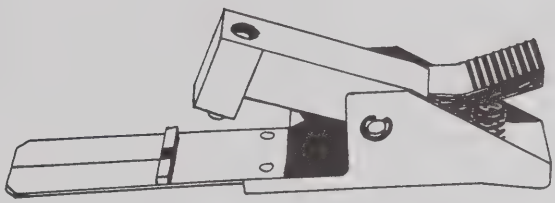
Coating Removal Tool - Typical



Miller® Tool

The plastic coating is removed from the individual fibers using a coating removal tool. These tools are made using precision cutting blades or preset openings. Shown is a typical coating removal tool.

Cleaving Tools - Typical



Fitel® Cleaving Tool

Cleaving tools are the most critical and important of all fiber optic specialty tools. Cleavers are used to score the glass once the coating has been removed and the fiber cleaned. After scoring, the glass is cleaved. For fusion splicing, the angle of the face of the cleaved glass must be within 1 degree from perpendicular. Cleavers range in price from $200 to $2,000. The more expensive cleavers give more consistent cleaves. The least expensive ones are used in emergency restoration kits for mechanical splices where the angle of the cleave is not as critical.

Grounding and Bonding

1.0 General

2.0 Grounding and Bonding

2.1 Grounding and Bonding Components

3.0 Grounding and Bonding Practices

3.1 Aerial Cable

3.2 Subsurface Plant

1.0 General

The primary purpose for the grounding and bonding of broadband and CATV systems is to protect personnel that are working on or around the system in addition to the public. For simplicity in presentation, the broadband and/or CATV system will hereinafter be referred to as *the system*. The secondary purpose for grounding and bonding of *the system* is to establish a reference ground potential, i.e., a common reference voltage for all of the electronics connected to the system.

The *grounding network* establishes an effective electrical ground for *the system* and its associated hardware. This *grounding network* will provide a termination point for currents that might be present in the event that *the system* inadvertently becomes energized.

Continuity bonding of the broadband plant will ensure that no hardware and/or cables in *the system* are electrically isolated from the *grounding network*. *Continuity bonding* is simply referred to as *bonding*. *Bonding* is intended to minimize the potential (voltage) differences between conductive surfaces.

Energization will be considered in this section as the unwanted presence of high voltages on the conductive surfaces of *the system*. Energization can be caused by direct contact with high voltage wires and equipment or by induced voltages caused by conductive surfaces of *the system* being in close proximity to changing electric and magnetic fields such as those caused by high voltage wires and lightning. Dangerously high voltages can be present within *the system*, that is, on *the systems* conductive surfaces, even when *the system* is not in direct contact with an energized conductor.

Lightning often induces high voltages onto *the system* without directly striking the system. The induced voltages are typically extremely high, but of very short duration. Proper *bonding* and *grounding* will dissipate these voltages. The over-voltage conditions caused by lightning are harmful to electronic devices.

Conductors and cables that are in close proximity to other current carrying conductors will have voltages induced onto them. The proper *bonding* and *grounding* of *the system* will dissipate the induced voltages. Induced voltages are usually continuous and accordingly the *bonding* and *grounding* of *the system* must be maintained throughout the lifetime of *the system*. Some control of induced voltages can be maintained by the proper spacing of *the system* from other electrical conductors, especially high voltage conductors. See **Appendix C: Vertical Clearances of Communications Cables from Supply Conductors and Equipment.**

Caution: As conductive surfaces are brought into the close proximity of high voltages, flash-over can occur. Flash-over is the transfer of electrical energy from one conductive surface to another without direct contact of the two surfaces.

2.0 Grounding and Bonding

Grounding connections and *bonding* connections should be made with materials and techniques that ensure the combination of metals will not corrode during the lifetime of the plant with the consideration of environmental exposure. *Grounding* and *bonding* connections may be made by brazing, welding, compression connections, and mechanical connections. Mechanical connections will only be considered in this text.

Electrical Grounds

The *grounding network* consists of many electrical *grounds* throughout *the system*. The *grounds* are established by various methods known to offer a low impedance path for current flow. *Grounding* methods are identified in this section.

Bonding

Bonding is the method by which all conductive cables and messengers are continuously connected. Current flow is enabled from conductive cables and messengers to ground by the continuous bonding of the plant to the *grounding network*. *Bonding* hardware and methods are identified in this section.

Note: Jacketed cables should be bonded to the *grounding network* where the jacket is accessed for splicing purposes. There is no need to ground or bond all-dielectric cables. Coaxial cables are electrically connected to the *grounding network* at the connector/cable interface when the equipment that the cable is connected to is bonded to the *grounding network.*

2.1 Grounding and Bonding Components

Components used in the methods for *grounding* and *bonding* can be seen in **Figure 6.1: Typical Grounding and Bonding Hardware Configuration.**

The components and methods used in the grounding and bonding of *the system* are specified as follows:

Ground Rods

Ground rods are electrical *grounds* and are also called grounding electrodes. Ground rods should be at least 8 feet in length with a conductive and non-corrosive outer surface. Copper-clad ground rods should be at least ½ inch in diameter.

Multiple ground rods may be installed to desirably reduce the ground resistance. Distance between the ground rods arranged as multiple ground rods should not be less than 6 feet. Multiple ground rods should be bonded together and connected to a common

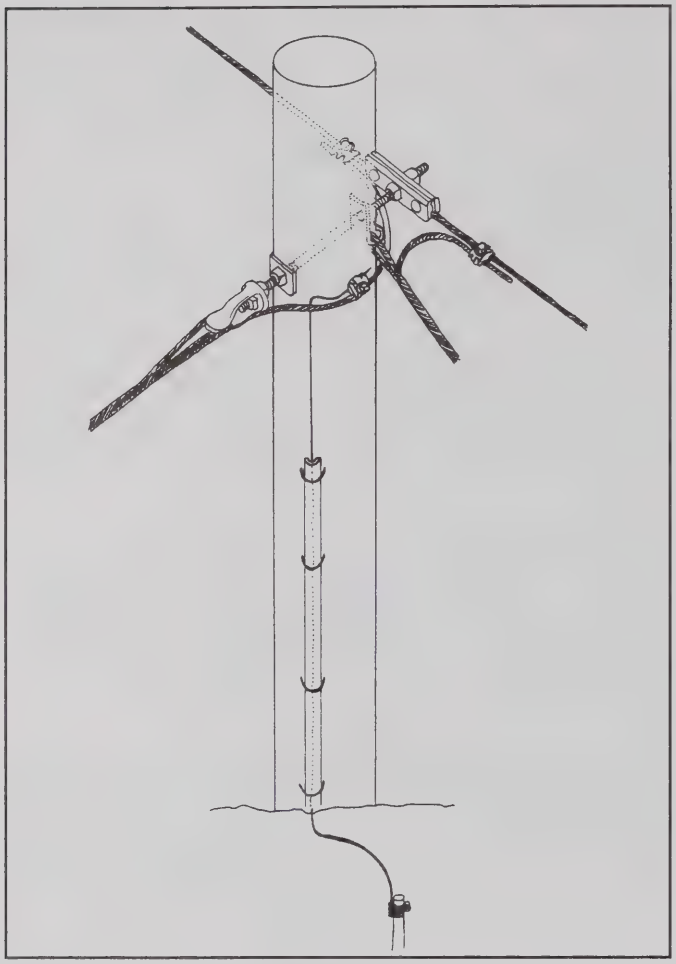


Figure 6.1:
Typical Grounding and Bonding Hardware Configuration

ground wire. Ground rods should be buried level with or below the ground level unless the ground rod is installed in a vault or enclosure. Ground rods installed in vaults or enclosures should be buried to a minimal depth of 7.5 feet. Driven ground rods that encounter a rock bottom are not required to be buried to a depth of 8 feet.

Ground rods should not be installed within 10 feet of high pressure pipelines that transport flammable materials.

If a ground rod is installed specifically for *the system*, then a dedicated ground wire is required to connect *the system* and the dedicated ground rod.

Connection of the ground wire to the ground rod should be made by a corrosion resistant clamp.

Ground Rod Clamp

A ground rod clamp is used to connect the ground wire to the ground rod. The ground rod clamp should be a corrosion resistant clamp, plug, fitting, braze or weld. Typically a bronze ground rod clamp is used. See **Figure 6.2: Typical Ground Rod Clamp.**

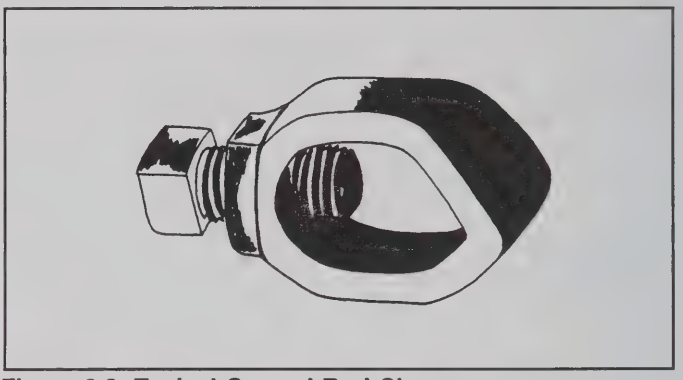


Figure 6.2: Typical Ground Rod Clamp

Ground Wires

Ground wires provide means for interconnection of the messenger and cables to the ground rod. Ground wires are also referred to as grounding conductors. A ground wire may already exist on aerial structures (poles). The size of the existing ground wire is determined according to the fault currents of the services on the structure.

Ground wires dedicated to *the system* should be made of copper and of a size not less than AWG No. 6. The ground wire should be not be spliced when practically possible. No splice should be made in buried ground wire.

Ground wire should be connected to the ground rod by using means of a bolted clamp, commonly called a ground rod clamp. The opposite end of the ground wire should be connected to *the system* by means of a suitable connector that will not corrode. A bi-metal connector is required if the ground wire is connected to galvanized steel strand or hardware. If there is insulation or nonconducting material on the ground wire, the insulation or nonconducting material should be removed before any connection is made to the ground wire to ensure a good electrical connection.

Ground wires should be installed in straight lines whenever possible. Any bends made in the ground wire should be gradual. Ground wire should be secured to the structure with copper clad staples if the wire might be pulled away from the structure.

Ground Wire Staples

Copper clad staples are used to affix the ground wire to the structure when the structure is wooden. Copper staples are used to prevent any corrosion between the staple and the ground wire. Structures of materials other than wood usually have specific attachment hardware or accommodations for the attachment of the ground wire to the structure.

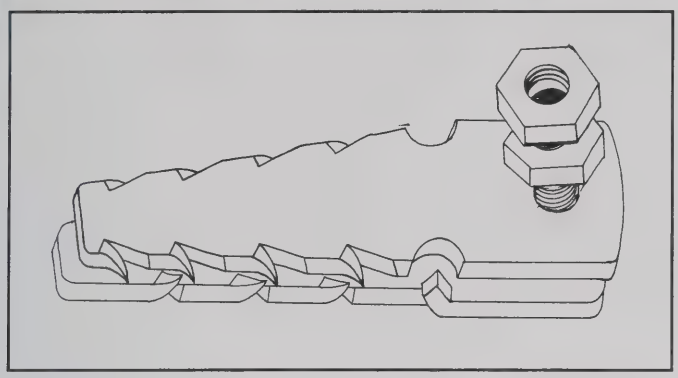


Figure 6.3: Typical Fiber Optic Cable Grounding Clamp

Ground Wire Molding

A nonmetallic ground wire molding should be placed over eight feet of the ground wire that is above ground level on the the pole. The molding is typically held in place by galvanized steel staples.

Fiber Optic Cable Grounding Clamp

Fiber optic cables with metallic armor and/or steel strength members are connected to the grounding network using a special fiber optic cable grounding clamp. See **Figure 6.3: Typical Fiber Optic Cable Grounding Clamp.**

Bonding Clamps

Bonding clamps are made in various types and many styles. Corrosion at the bonding clamp is controlled by using a bonding clamp that will not corrode when in contact with another dissimilar metal. If there is insulation or nonconducting material on the bonding surfaces, the insulation or nonconducting material should be removed before any connection is made. Three types of bonds are present in the system. The types of bonds and the hardware that is specific to the bonds are as follows:

- Copper to Copper Bond - this bond is usually made with a bronze split bolt clamp as seen in **Figure 6.4: Split Bolt Bonding Clamp.**

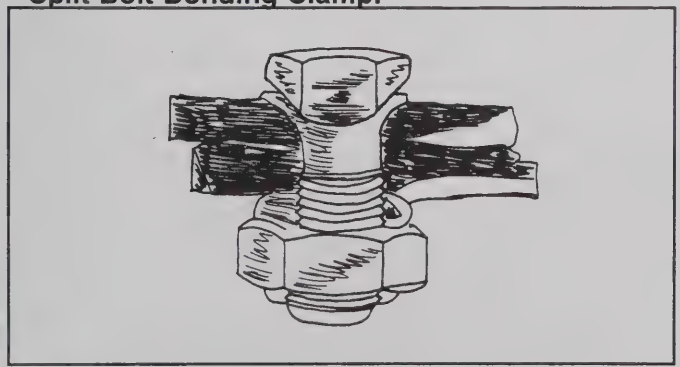


Figure 6.4: Split Bolt Bonding Clamp

- Copper to Galvanized Steel or Aluminum Bond - this bond is usually made with a bi-metal clamp that has bonding surfaces compatible to the two different materials being bonded, it is important to properly install this clamp due to the different bonding surfaces. One side of the clamp is specified for copper and the other for galvanized steel or aluminum. A typical clamp can be seen in **Figure 6.5: Bi-metal Bonding Clamp**.

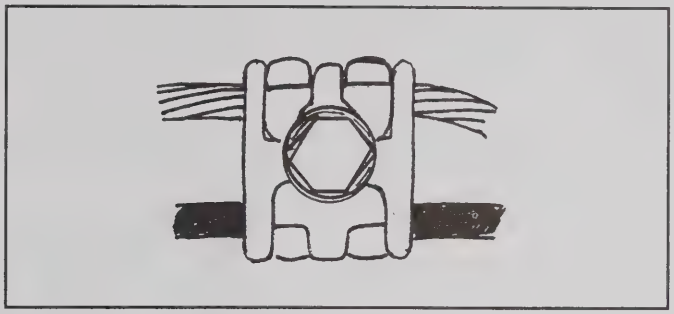


Figure 6.5: Bi-metal Bonding Clamp

- Galvanized Steel to Galvanized Steel Bond - this bond is usually made with a simple bonding clamp, this clamp can be easily confused with the bi-metal bonding clamp, a typical clamp can be seen in **Figure 6.6: Bonding Clamp.**

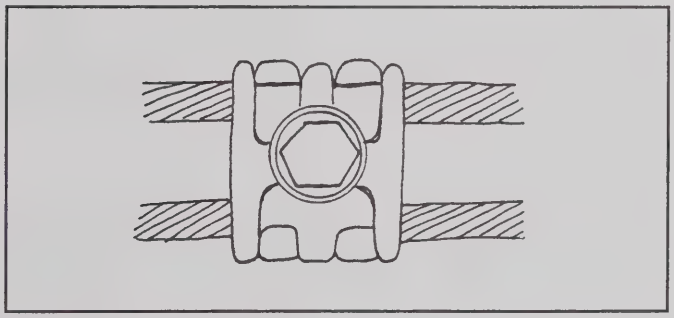


Figure 6.6: Bonding Clamp

3.0 Grounding and Bonding Practices

3.1 Aerial Cable

Aerial coaxial and fiber optic cables are installed in two configurations. In the first configuration, the cables are directly lashed to a messenger (strand). The messenger is commonly referred to as *cable bearing strand.* The second configuration is commonly called a *self-support, figure-eight*, or *integrated messenger* (IM) cable configuration. Grounding of aerial plant may be accomplished by means of pole-butt plate or wire wraps in place of a driven ground rod. The employed method of grounding should provide a ground of adequately low resistance.

Cable Bearing Strand

Cable bearing strand should be grounded or bonded to the *grounding network* at least 8 times per mile of plant.

Guys should be bonded to or an integral part of the *cable bearing strand.*

All messengers and guys of *the system* on the same supporting structure should be bonded together with AWG No. 6 copper wire.

Self Support
Self support strand should be grounded or bonded to the *grounding network* at least 8 times per mile of plant.

Guys should be bonded to the self support strand.

All messengers and guys of *the system* on the same supporting structure should be bonded together with AWG No. 6 copper wire.

3.2 Subsurface Plant

Underground Plant
Underground plant is defined as plant that is placed inside conduits and routed to vaults and manholes. Grounding and bonding will be done inside the vaults and manholes.

Ground wire and ground rods should be installed in areas of limited exposure to mechanical damage.

All cables, ground wires, metal ducts, and other accessible grounded power systems in the same vaults and manholes should be bonded together and grounded to the same grounding network. AWG No. 6 copper wire should be used for bonding *the system* to the *grounding network.*

Jacketed cables should be bonded to the *grounding network* where the jacket is accessed for splicing purposes. There is no need to ground or bond all-dielectric cables. Coaxial cables are electrically connected to the grounding network at the connector/cable interface when the equipment to which the cable is connected is bonded to the *grounding network.*

Direct Buried Plant
Direct buried plant is defined as plant that is in direct contact with the earth. *Grounding* and *bonding* will be done at enclosure, vault, and hand-hole locations.

Ground wire and *ground rods* should be installed in areas of limited exposure to mechanical damage. Buried *ground wire* should be continuous and free of joints and connections. *Ground wire* should be laid slack to prevent being broken during ground movement.

Jacketed cables should be bonded to the *grounding network* where the jacket is accessed for splicing purposes. There is no need to ground or bond all-dielectric cables. Coaxial cables are electrically connected to the *grounding network* at the connector/cable interface when the equipment to which the cable is connected is bonded to the *grounding network.*

Guys and Anchors

1.0 General
Guy Wires
Safety Factors
Crossings
Down Guys

2.0 Types and Methods of Guying

3.0 Types of Anchors

4.0 Anchor Attachment

5.0 Guy Construction

1.0 General

A guy and anchor is used to counteract the horizontal component of forces placed on poles by the strand and cable. The guy and anchor should typically:

- keep the pole in a desirable position
- counteract the unbalanced forces due to construction techniques
- counteract abnormal forces on the pole due to wind and ice loading of the strand and cable

NESC Rule 264A states that:

"When the loads to be imposed on supporting structures are greater than can be safely supported by the structures alone, additional strength shall be provided by the use of guys, braces or other suitable construction. Such measures shall also be used, where necessary to prevent undue increase in sags in adjacent spans, as well as to provide sufficient strength for those supports on which the loads are considerably unbalanced, for example, at corners, angles, dead-ends, large differences in span lengths and changes of grade in construction."

Applicable codes for guying can be found in NESC Section 26.

Guy Wires

A *guy wire* is the strand that connects the pole line hardware, particularly the guy attachment hardware, to the anchor. Being strand, the rated breaking strength of the guy is the same as that for the strand. See **Table 8.1. Mechanical Properties of Select Strand.**

Safety Factors

Safety factors of overhead lines are accounted for by the NESC specification that overhead lines should not be subjected to tension greater than 60% of the breaking strength of the line (strand). *Guys* and *anchors* have a *safety factor* specified in NESC 262C. The *guy* should be constructed of such material and dimension such that the loading on the guy multiplied by an appropriate overload capacity factor does not exceed 90% of the rated breaking strength of the *guy*.

Crossings

Crossings are defined by NESC 241C and are generally defined to be where overhead lines cross:

- other overhead lines not in the same pole-line
- highways
- bridges
- railways
- rivers and bodies of water

Guys used at *crossings* may require a change in *construction grade* as per NESC 241C dependent on the *crossing* circumstances.

Down Guys

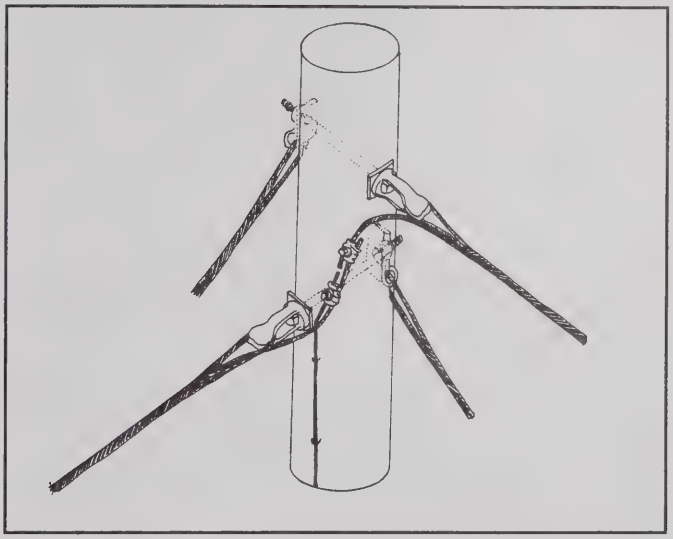
A *down guy* is the general name for the *guy wire* and associated hardware on all guys.

Down guys consist of a length of strand that is attached to pole-line hardware and to an anchor. The anchor is used to transfer a horizontal component of force from the pole to the ground via the *guy wire*. The anchor may be of several types as specified in **Section 7.3**

Down guys may also be referred to as *anchor guys* or simply *guys*.

2.0 Types and Methods of Guying

Head Guy



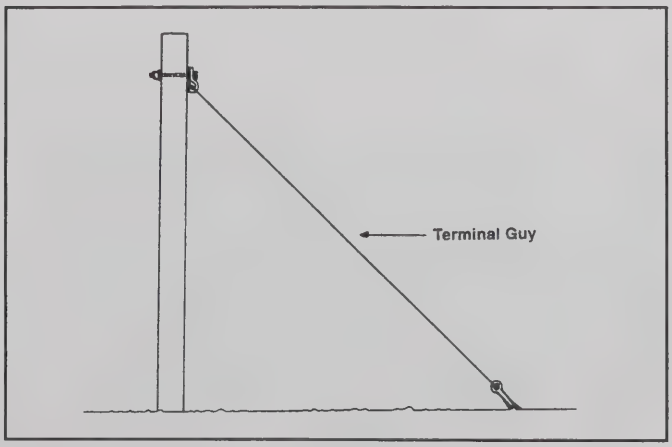
Head guys are placed in line with the strand routing.

A *head guy* may be used as a *terminal guy* or two can be used in a location where the strand changes direction.

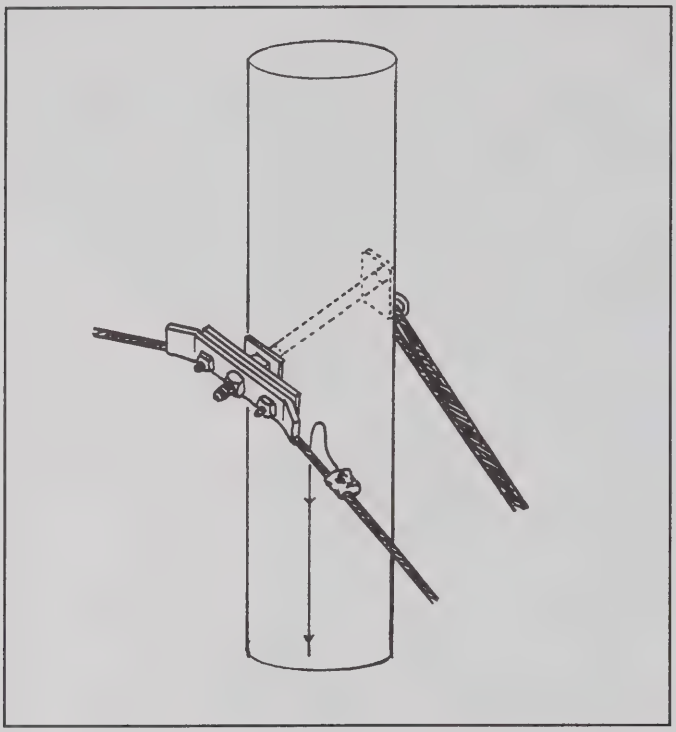
Head guys may also be referred to as *line guys*.

Terminal Guy

Terminal guys are used at the end of pole lines.



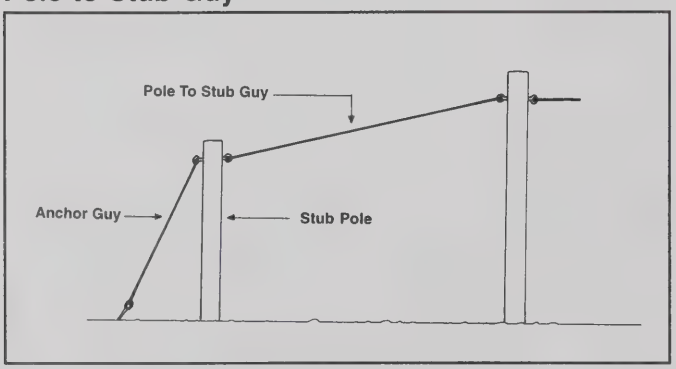
Side Guy



Side guys may be used when the strand changes directions.

The *side guy* is in line with the angel that bisects the strand routing. Careful engineering analysis should be made to insure that the side guy does not cause excessive forces to be placed on the guy, anchor, and associated hardware.

Pole-to-Stub Guy

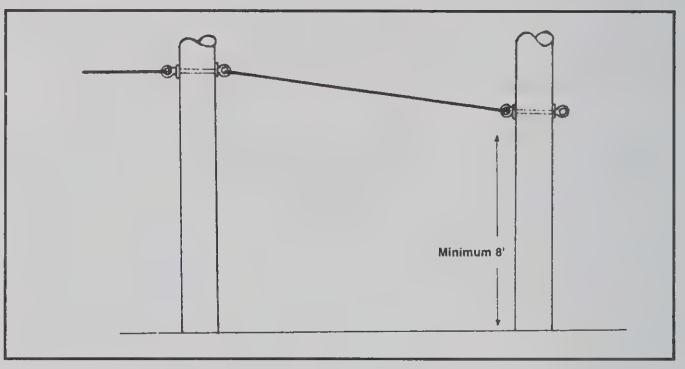


Pole-to-Stub guys are used to establish clearance for the guys. *Pole-to-stub guy*s are attached to a *stub pole.*

This type of guy is used when a *head guy* cannot be placed at a pole because of an obstacle in the immediate vicinity of the pole. *Pole-to-stub guys* are often used to provide guy clearance over roads.

A *pole-to-stub guy* may be called a *stub guy.*

Pole-to-Pole Guy



Pole-to-pole guys utilize an in line pole as an anchor.

A *pole-to-pole guy* may also be called a *span guy* or an *overhead guy.*

The attachment to the pole used as an anchor should not be greater than eight feet from the base of the anchor pole.

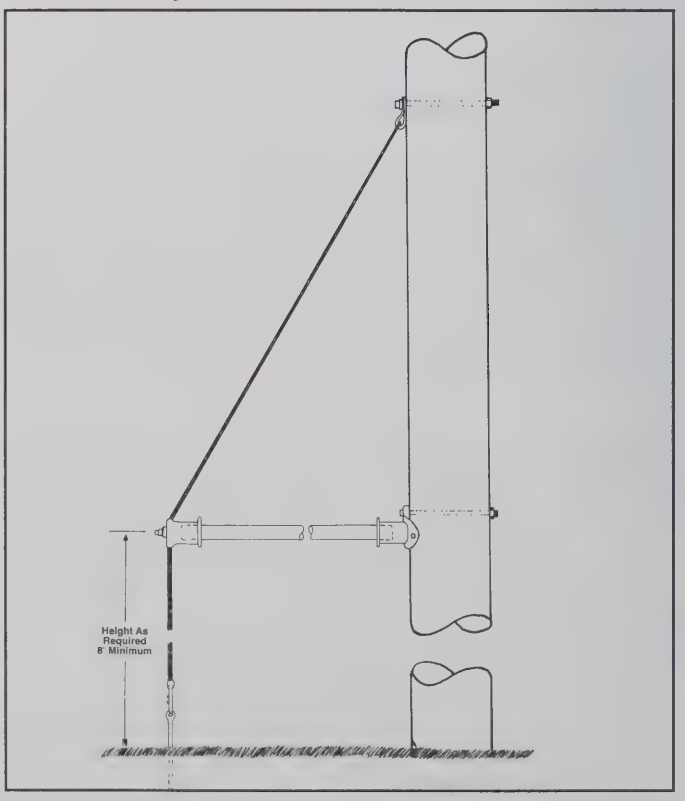
Storm Guy

Storm guys are used when a straight pole line is subjected to extreme transverse forces typically in the form of wind.

There may be two storm guys on a pole, both at a ninety degree orientation to the pole line.

A *storm guy* may also be called a *line guy.*

Sidewalk Guy

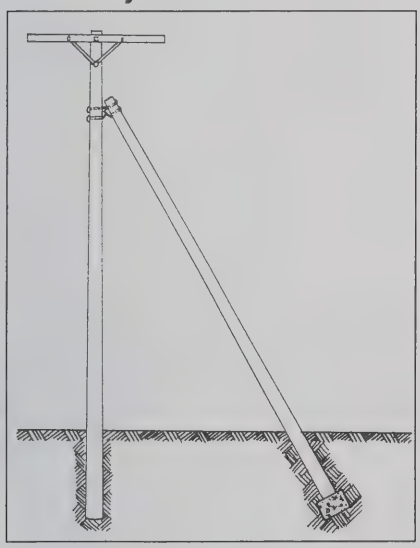


Sidewalk guys use a horizontal strut to provide overhead clearance when a head guy causes a hazard to traffic beneath the guy. *Sidewalk guys* are useful when the placement of the anchor is critical.

The horizontal *strut* causes additional forces to be placed on the pole where the strut contacts the pole.

The strut, typically a 2½ inch galvanized steel pipe, should be placed eight feet from the ground beneath the strut.

Push Guy



A pole is used as a guy or brace on another pole in a *push guy* configuration. *Push guys* may be used in locations where it is impossible to use conventional guys. Lack of sufficient right-of-way often dictates the use of *push guys.*

Push guys may also be referred to as *push poles.*

3.0 Types of Anchors

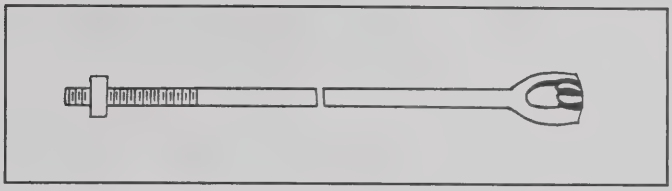
Anchors are used to transfer the horizontal component of force from the pole to the ground. The holding power of an anchor is a measurement of how effective the anchor is at transferring the force to the ground.

Soil conditions effect the holding power of the anchor. Soil conditions are divided into classifications such as sand, clay, or hard pan. The soil classification for the location of the anchor installation should be considered when specifying the size and type of anchor in addition to the component of force that the anchor must transfer.

Anchor manufacturers provide holding power specifications for the various types and sizes of anchors in the various soil conditions.

All *anchors* and *anchor rods* should be installed in line with the direction of pull of the attached down guy. When possible, *rock anchors* should also be installed in this manner, but an exception can be made for *rock anchors.*

Anchor Rods

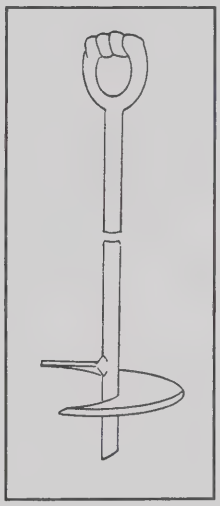


Anchor rods connect the anchor and the guy wire.

Anchor rod strength specifications are provided by anchor manufacturers.*Anchor rods* are also called *guy rods.*

Screw Anchor

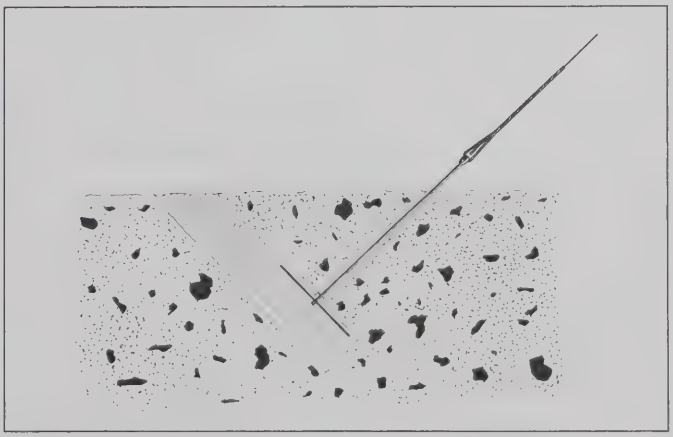
Screw anchors are designed to be directly torqued into the ground with a power anchor driver although *screw anchors* can be installed manually. Minimal ground disturbance results with *screw anchors.*



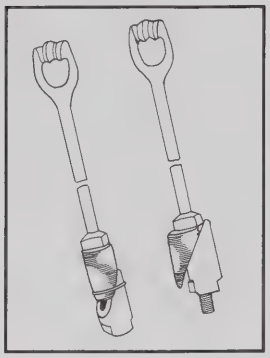
Never-Creep Anchor

Never-Creep Anchors are anchors designed for use in soft soil where conventional anchors are less effective. The *never-creep anchor* is installed by driving the *never-creep anchor rod* to intersect a perpendicular bore hole used for placement of the plate of the *never-creep anchor.* The bore hole is refilled and compacted.

Never-creep anchors are also called *plate-type anchors.*



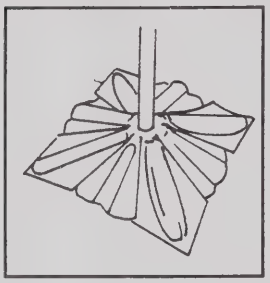
Rock Anchor



Rock Anchors are designed to be expanded in holes bored in rock or concrete.

Rock Anchors are also called *concrete anchors.*

Expansion Anchor

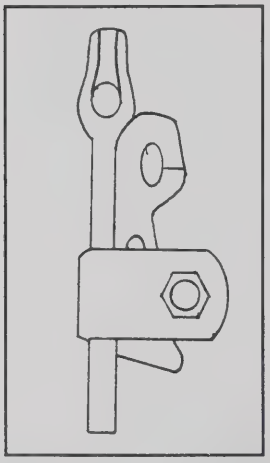


Expansion Anchors are placed into bored holes while the *expansion anchor* is in the closed position. The *expansion anchor* is struck several blows with a special expanding bar, causing the anchor to expand into the undisturbed earth at the base of the bore hole.

Toggle Anchor

Toggle anchors are mechanically driven into the earth. The anchor is toggled into place by an upward pull on the anchor. Holding power is determined by gauge readings, anchor size, and soil type.

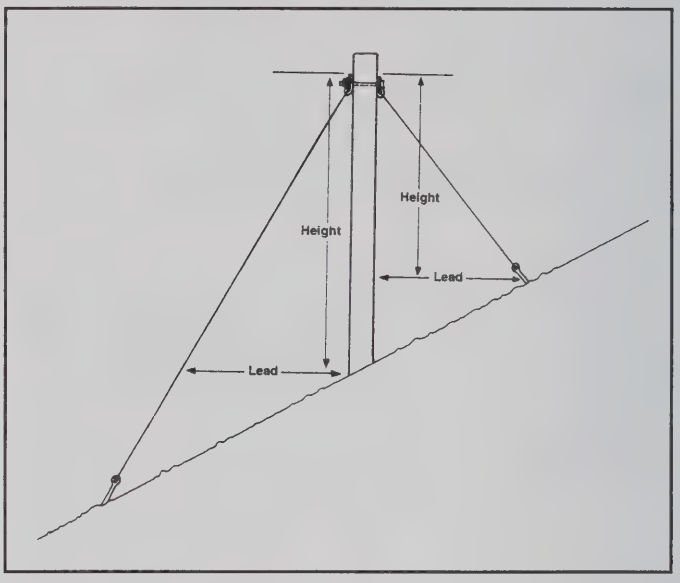
4.0 Anchor Attachments



Anchor attachments are referred to as *auxiliary eyes.* An *auxiliary eye* is used to provide for attachment of an additional guy to an existing anchor and guy. *Auxiliary eyes* can be added to anchors that have sufficient holding power to support the additional force transferred to the anchor. Careful engineering analysis should be used in determining the holding power of an anchor and the effect of the additional load on the anchor.

5.0 Guy Construction

Lead-to-Height Ratio



The lead-to-height ratio restricts the vertical compressive load on the pole while counteracting the horizontal forces placed on the pole by the strand and cable. The lead-to-height ratio that must be maintained is a function of the guy and anchor materials and the allowable force on the materials. The lead-to-height ratio should be specified by the system engineer due to the variance in hardware and soil conditions.

Guy Wire Tension

Guy wire tension counteracts the horizontal forces placed on the pole by the associated strand and cables. *Tension* in the guy wire may be higher than the tension in the associated strand and cable due to the angle of the guy wire in relation to the stand and cable.

The breaking strength of the guy wire is a function of the strand size. Minimum breaking strength of the guy wire (strand) is specified in **Table 8.1. Mechanical Properties of Select Strand.**

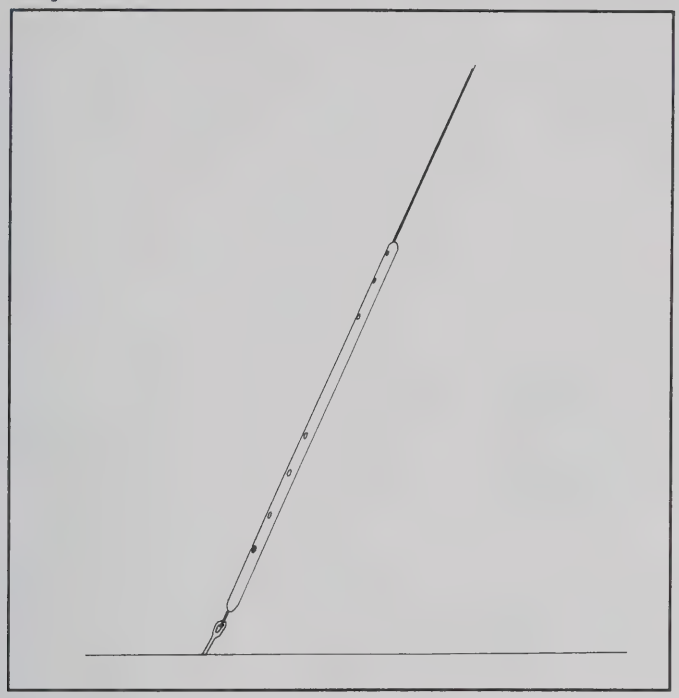
Accordingly, allowable *guy wire tension* is a function of anchor size and type, guy wire size, lead-to-height ration, and location.

Allowable *tension* in the *guy wire* is given as a percentage of the breaking strength of the strand as per NESC Section 26, with regard to appropriate safety factors.

Guy Wire Attachments

Guy wire attachments enable attachment of the guy to the pole. *Guy wire attachments* should be made directly to the pole-line hardware that is supporting the strand and cable that is placing the horizontal forces on the pole.

Guy Guards



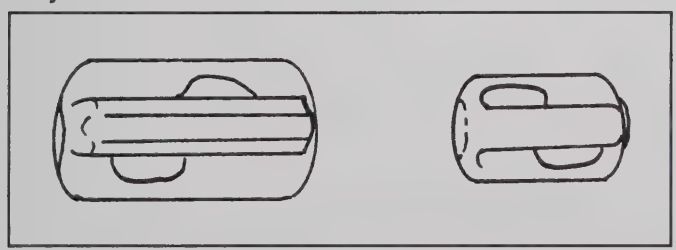
Guy guards should be placed on the ground end of guys exposed to pedestrian traffic. *Guy guards* should be of pattern or color to provide a conspicuous indication of the presence of the guy.

Grounding and Bonding Guys

Guys are grounded and bonded to prevent the continued energization of the guy during inadvertent contact with electrical conductors.

Grounding and bonding is accomplished using standard bonding and grounding hardware as identified in **Section 6.**

Guy Insulators



Guy insulators are installed on ungrounded guy wires attached to structures (poles) carrying energized conductors. The guy insulators are installed between the guy attachment hardware and the anchor attachment and in accordance with NESC 279. The insulator should always be located at least 8 feet above the ground. The insulator should also be placed such that if any guy sags down upon another, the insulator will not become ineffective.

Strand Construction Practices

1.0 General

2.0 Strand Installation Concerns

2.1 Strand Selection

2.2 Mid-Span Clearances

2.3 Pole-line Framing Methods

3.0 Installation Methods

3.1 Back-pull method

3.2 Drive-off method

1.0 General

This section of the CommScope Construction Manual reviews strand placement techniques typical to the industry. These techniques vary with manpower and equipment availability.

The messenger for cable support is commonly referred to as strand and will be referred to as such in this section.

2.0 Strand Installation Concerns

Mechanical considerations must be made prior to the installation of cable bearing strand. The weight per unit length of the cable or cable bundle being installed onto any strand must be considered. A cable bundle is defined as more than one cable collectively lashed to the strand. Tension placed on the strand by the installation of cables and the tension due to wind and ice loading must be considered in the selection of strand size and construction methods. Construction grades dictate additional safety factors that must be considered. Sag of the cable and strand, i.e., final sag, and mid-span clearances, also effect the tension placed on the strand and must be considered. A qualified engineer should take these considerations into account during selection of strand size and construction methods.

Strand installation is recognized as one of the most hazardous tasks in cable plant construction. The movement of the strand, the dynamic forces being placed on the pole-line, and the presence of energized conductors all contribute to the potential hazards of the task. Skill at the required task, communication, and hazard recognition are critical.

2.1 Strand Selection

The mechanical properties of typical strand can be found in **Table 8.1: Mechanical Properties of Select Strand.**

2.2 Mid-span Clearances

Mid-span clearances of the strand, after installation of the cables onto the strand, are critical. Required mid-span clearances are specified in **Table 4.1: Vertical Clearance of Wires, Conductors, and Cables Above Ground, Roadway, Rail or Water Surfaces.** The specified clearances in **Table 4.1** must be maintained when worst case wind and ice loading occurs as specified in Section 25 of the National Electric Safety Code (NESC). Sag analyses are typically performed using published charts and graphs. CommScope performs sag and tension analyses of CommScope cables by use of the interactive computer software, SpanMaster® Release 2. The support documentation for SpanMaster® Release 2 is **Appendix D** of this manual. The software for SpanMaster® Release 2 can be obtained from CommScope District Sales Managers.

2.3 Pole-line Framing Methods

Pole-line hardware installation methods are identified in Section 11 of this manual. The act of installing pole-line hardware is typically called framing. The following hardware configurations are identified in **Section 11:**

- Straight line pole
- Angled pole
- Mid-span crossover
- Dead-end
- False dead-end
- Double dead-end
- Line pole dead-end

Make-ready of existing hardware located on aerial structures (poles) may be required to ensure proper clearances. Relocation or the upgrade of aerial facilities should be coordinated with the owner of the structure and the owner of the facilities that must be relocated or upgraded.

Table 8.1: Mechanical Properties of Select Strand

	1/4 inch EHS strand	5/16 inch (6M) strand	3/8 inch (10M) strand
Weight (lb./ft.)	0.121	0.225	0.270
Diameter	0.25	0.3125	0.375
Ultimate breaking strength (lb.)	3900	3600	6900
Modulus of elasticity (psi)	$2.7x10^7$	$2.1x10^7$	$2.1x10^7$
Cross-sectional area ($in.^2$)	0.0326	0.0609	0.0753
Coefficient of expansion/°F	$0.64x10^5$	$0.64x10^5$	$0.64x10^5$

3.0 Installation Methods

The installation of strand and cable is accomplished by many methods. This subsection relates two methods of strand installation where the cable is not lashed to the strand at the time of strand placement. Pre-lash cable and drive-off cable placement methods are discussed in **Section 9** of this manual. Methods of winching strand into place exist but will not be reviewed in this section due to the infrequent use of this method.

The strand installation methods related herein are the stationary reel method, commonly called the back-pull method, and the moving reel method, also called the drive-off method. The choice of construction methods is dictated by the circumstances at the construction site, equipment availability, and manpower availability. Additional concerns in strand placement are itemized after both methods are presented in this text.

Use of the following specialized equipment will make the installation of the strand substantially safer.

- Insulated gloves - Insulated gloves should be worn by all personnel that are in contact with the strand that is being pulled into place. Insulated gloves should be worn until the strand is bonded to the *grounding network.* Care should be taken to ensure that the strand is not directly contacted by construction personnel. Routine inspection and certified testing of insulated gloves is required.
- Reel Brakes - Reel brakes are used to prevent unwanted pay-off of strand from the cable trailer or reel stand. Proper brake adjustment will prevent the strand from sagging into pedestrian or vehicular right-of-ways while the strand is being pulled into place. Strand brakes should be used in conjunction with reel brakes.
- Strand brakes - Strand brakes are used to maintain the tension in the strand by preventing the backslipping of the strand through the pole-line hardware during installation. Reel brakes should be used in conjunction with strand brakes.
- Traveling grounds - Traveling grounds are installed at the location where the strand is spooled from the cable trailer or reel strand. The traveling ground must be connected to an electrical ground to provide a continuous ground for the strand that is being pulled into place. STRAND SHOULD NEVER BE INSTALLED WITHOUT THE PROPER INSTALLATION AND USE OF A TRAVELING GROUND when using the back-pull method. Traveling grounds can be removed only after the strand is bonded to the *grounding network.*

3.1 Back-Pull Methods

Make-ready - Make-ready is assumed to be completed prior to commencement of the strand placement task.

Hardware placement - Placement of the pole-line hardware can be done when the construction lineman pulls the strand into place. Guys should be installed and tensioned to anchors when the strand is pulled into place to prevent placing any undue forces on the pole-line.

Trailer placement and set-up - The trailer or reel stand should be placed in line with the pole-line at the dead-end pole of the pole-line. The strand should pay-off the top of the strand reel. The trailer should be a minimal distance, (two times the hardware attachement height),

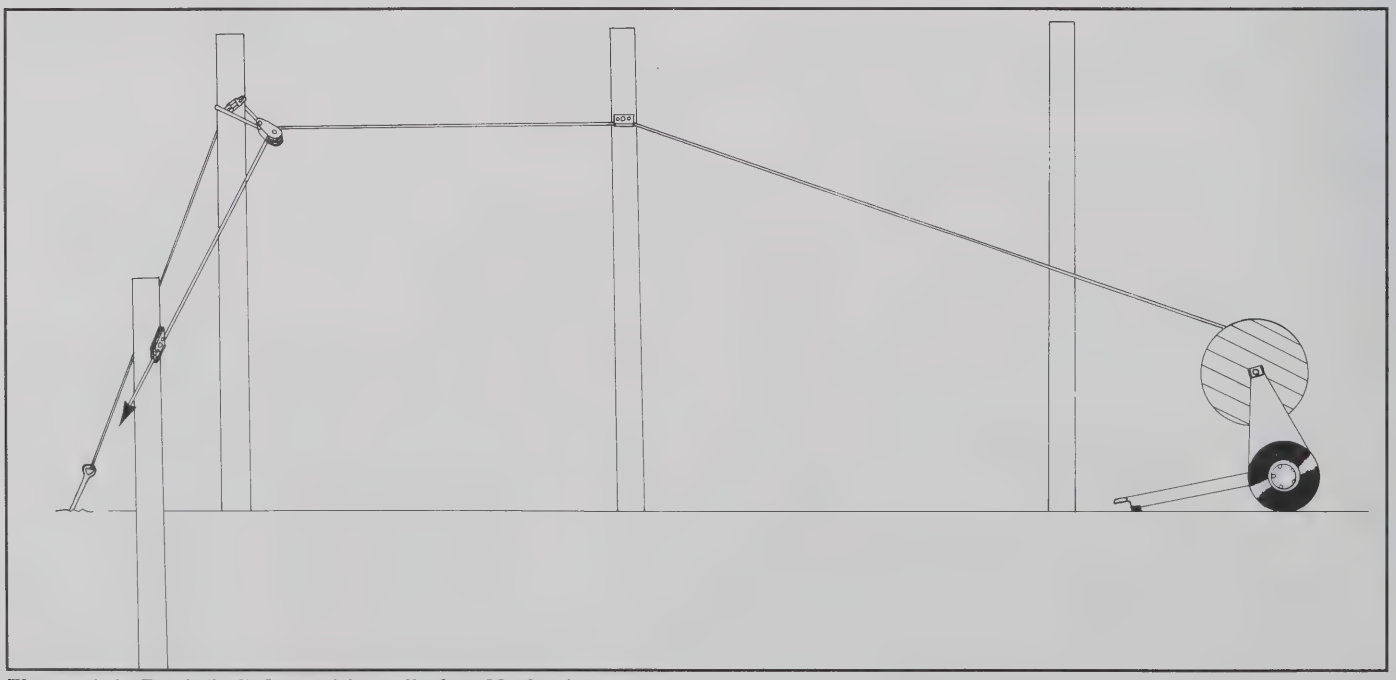


Figure 8.1: Back-Pull Strand Installation Method

from the pole at which the strand first contacts the pole-line hardware. Trailer wheels should be chocked.

First pole - The first pole will typically not be framed. New strand will be pulled past this pole to the second pole. If the strand encounters a crossing at this location or if the strand objectionably sags onto some object, the pole may be framed and a snatch block used to support the strand, giving the strand the required mid-span clearance.

Second pole - At the second pole, the pole-line hardware will be installed. At this pole and all remaining poles, the suspension clamp (when used) should be loosely installed and the strand placed into the clamp. The clamp should only be tightened sufficiently to prevent the strand from being pulled from the clamp and to secure the clamp onto the framing hardware.

Dead-end poles - Poles that use dead-end framing techniques often do not have an associated suspension clamp that can be used to allow the strand to be pulled through the clamp and are usually at turns in the pole-line. Use of a snatch block at these locations will allow the strand to be continuously pulled by facilitating strand movement past this point.

Final pole - At the final pole in the pole-line, dead-end construction techniques will typically be used. The strand will be attached to the hardware with a dead-end strand grip or a strandvise. The strand may be attached to existing strand at this location by a strand splice.

Tensioning - The construction lineman will visit each pole that uses dead-end framing techniques and use a hoist and strand grip to tension the strand. Dead-end strand grips or strandvises will be used for attachment of the strand to the framing hardware. This procedure will be repeated as the construction crew proceeds from the last pole back toward the first pole. At the first pole, the strand may be attached to existing strand by using a strand splice.

Hardware cleanup - All clamps will be tightened as the construction crew proceeds back toward the first pole. Grounding and bonding should be completed when the hardware is tightened. Where slight differences of tension are required span to span, the tension can be adjusted prior to tightening the suspension clamp.

3.2 Drive-Off Methods

Make-ready - Make-ready is assumed to be completed prior to commencement of the strand placement task.

Hardware placement - Placement of the pole-line hardware can be done when the construction linemen pull the strand into place. Guys should be installed and tensioned to anchors when the strand is pulled into place. This is done to prevent placing any undue forces on the pole-line.

First pole - Dead-end framing techniques are usually employed at this location unless the strand is connected to existing strand. IT IS IMPORTANT THAT THE STRAND BE GROUNDED AT THIS LOCATION.

Second pole - At this pole and all remaining poles, the suspension clamp (when used) should be loosely installed and the strand placed into the clamp. The clamp should only be tightened sufficiently to prevent the strand from being pulled from the clamp and to secure the clamp onto the framing hardware.

Dead-end poles - The strand will be tensioned at each pole with dead-end framing. The construction lineman will use a hoist and a strand grip to tension the strand. Preformed strand grip or strandvises will be used for attachment of the strand to the framing hardware.

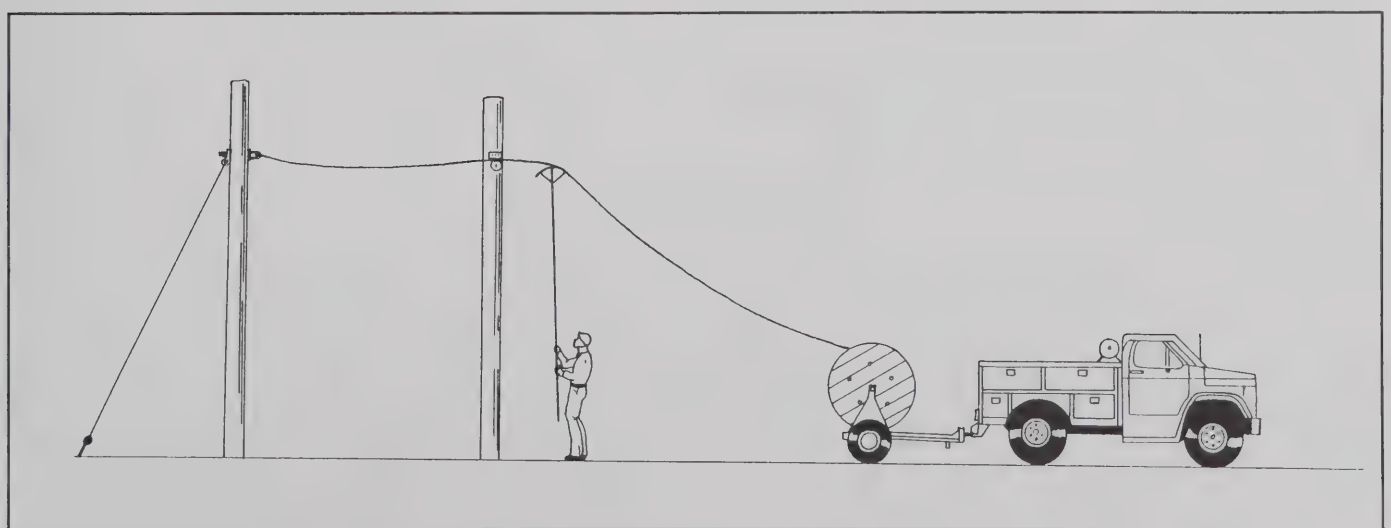


Figure 8.2: Drive-Off Strand Installation Method

Hardware cleanup - Hardware will be tightened after the strand is tensioned at the dead-end locations. Grounding and bonding should be completed when the hardware is tightened. Where slight differences of tension are required span to span, the tension can be adjusted prior to tightening the suspension bolt clamp.

Additional Strand Placement Concerns
The following concerns are pertinent to the placement of new strand:

- Strand splices should be placed outside the pole framing hardware, but within 18 - 24 inches of the pole.
- Traveling grounds should always be used in placing strand by the back-pull method.
- Swivels should be used on the end of the pull rope when pulling strand into place by the back-pull method.
- Never pull the strand with a vehicle without use of an automatic tension release device.
- Always install the strand on the same side of the pole as other cables and wires.
- Anchors and guys should be in place and tensioned prior to the start of strand placement by the back-pull method.
- Anchors and guys should be in place and tensioned when the pole-line hardware is placed when using drive-off strand placement methods.
- Be aware of the changes in sag of other pole-line facilities during the pulling and tensioning of the strand. Mid-span clearances and clearances between all messengers and conductors should be maintained.
- Strand should always be pulled from the top of the reel.
- Strand should be routed off the trailer so as to cause a downward force on the hitch.
- Trailer wheels should always be chocked when the trailer is not hitched to a vehicle.
- Strand brakes should be used at all crossings.

Aerial Cable Placement

1.0 General

2.0 Aerial Cable Placement Concerns
- 2.1 Pulling Tensions
- 2.2 Bending Radii
- 2.3 Expansion Loops
- 2.4 Excess (Slack) Cable Loops, Fiber Optic Cable
- 2.5 Installing Cable Grips
- 2.6 Tension on Cables During Lashing
- 2.7 Lasher Selection
- 2.8 Cable Lengths, Fiber Optic Cable

3.0 Aerial Cable Placement on New Strand
- 3.1 Back-pull (Stationary Reel) Method
- 3.2 Drive-off (Moving Reel) Method

4.0 Overlash Cable Placement

5.0 Integrated Messenger Cable Placement
- 5.1 Back-pull (Stationary Reel) Method
- 5.2 Drive-off (Moving Reel) Method

6.0 Other Placement Methods
- 6.1 Prelashing Methods

1.0 General

Mechanical stress causing damage to the cable is of great concern during the cable placement process. The cables can be damaged by exceeding the maximum allowable pulling tension or exceeding the minimum allowable bending radii. Deformation of the physical geometry of the cable may immediately effect the electrical or optical performance of the cable and may shorten the life expectancy of the cable. Deformation of the physical geometry of the cable usually results from impacts, elongation, flattening, kinking or longitudinal indentations. Coaxial cables are particularly affected by deformations of the cable geometry due to impedance being a direct function of the concentricity of the conductors.

Two methods of cable placement will be reviewed in this section. They are the stationary reel or back-pull method and the moving reel or drive-off method.

2.0 Aerial Cable Placement Concerns

Concerns related in subsections 2.0 - 2.8 are common to all aerial coaxial cable and fiber optic placement techniques.

2.1 Pulling Tension

Cables are pulled into place from the reel by applying force to the end of the cable. Excessive forces applied to the cable will cause the cable to permanently elongate. Permanent elongation of fiber optic cable may damage the optical waveguides by fracturing the glass. Deformations of the conductor geometry causes an impedance change in coaxial cable and also causes difficulty when installing connectors.

Pulling tension for all cable types are specified in the appropriate CommScope product catalog. AT NO TIME SHOULD THE MAXIMUM PULLING TENSION BE EXCEEDED. Good construction techniques and proper tension monitoring equipment are essential.

During cable placement, attention should be given to the number and placement of cable blocks. The amount of sag between the blocks and the amount of bending at the block does effect the pulling tension.

Break-away Swivels

Break-away swivels should be placed on each cable to ensure that the maximum allowable tension for that specific cable type is not exceeded. The swivel is placed between the cable puller and pulling grip. A break-away swivel is required for each cable.

Dynamometers

Dynamometers are used to measure the dynamic tension in the cable. These devices allow continuous review of the tension and accordingly a realization can be made of any sudden increase in pulling tension. Sudden increases in pulling tension can be caused by many factors such as a cable falling from a block or a cable binding against pole-line hardware.

Tail Loading

Tail loading is the tension in the cable caused by the mass of the cable on the reel and reel brakes. Tail loading is controlled by two methods. It can be minimized by using minimal braking during the pay-off of the cable from the reel. At times, no braking is preferred. Normally no braking is used when installing fiber optic cable. Tail loading can also be minimized by rotating the reel in the direction of pay-off.

2.2 Bending Radii

Cables are often routed around corners during cable placement. As cables are routed around the corners, pulling tension must be increased to apply adequate force to the cable to bend the cable around the corner. Tension is directly related to the flexibility of cable. Flexibility is a function of cable size and design.

The static bending radius of coaxial cable is the minimum radius that cable can be formed without electrical or mechanical degradation of the cable. Bending the cable in this manner is usually only done during splicing or final forming of the cable. The minimum bending radius of cable as specified in the CommScope coaxial cable product catalog is the static bending radius of the cable, i.e., the minimum bending radius when the cable is not loaded. The radius of the bend in the cable, as the cable is being pulled, is the dynamic bending radius.

Bending radius for fiber optic cable is given in loaded and unloaded conditions. Always review the specifications for the appropriate bend radii. Loaded means that the cable is under the maximum allowable pulling tension and is being bent simultaneously. Unloaded means that the cable is under no tension. Unloaded conditions occur at splice points, hand holes, vaults or other termination points. The unloaded bending radius is the radius allowed for storage purposes.

The dynamic bending radii of cables during the construction process are controlled by construction techniques and construction equipment. Corner blocks and set-up chutes have large radius bends and low friction surfaces that minimally contribute to the increase in pulling tension that is required to pull the cable through this equipment.

2.3 Expansion Loops

Coaxial Cable

The difference in the expansion and contraction coefficients of the strand and the coaxial cable must be considered during the design and construction of the system. Temperature change causes the cable and strand to contract or expand. Strand and cable expands and contracts at different rates due to the different materials of which the strand and cable is manufactured. The difference of the expansion and contraction rate is accounted for by using expansion loops to allow the movement of the coaxial cable in relation to the strand.

Procedures for use of bender boards and mechanical benders are supplied by the manufacturer.

Expansion loops made with more than one cable in a cable bundle should not be banded together inside of the loop. Independent movement of each cable should be allowed because of the different expansion and contraction properties of each cable type.

Loops should be selectively placed in the system to prevent the unrestrained movement of cables at bends in the cable when expansion and contraction occurs and to minimize the stress on the cable at the connector/cable interface. Loops are also required to be placed at intervals throughout the cable routing. The size and frequency of placement of the loops should be determined by a qualified engineer. Placement of the loops can be graphically reviewed in **Section 11**.

Fiber Optic Cable

Expansion loops are not required for fiber optic cables. A small two to four-inch loop at the pole-line hardware provides sufficient strain relief during the expansion and contraction of the strand.

Fiber optic cables that are lashed in the same cable bundle as coaxial cables can be routed directly along the strand when a coaxial cable expansion loop is encountered.

2.4 Excess (Slack) Cable Loops, Fiber Optic Cable

Excess (slack) cable is stored at locations where there might be a relocation of poles in an existing pole-line. Excess cable will be pulled out and lashed back onto the strand forming a loop. The cable will not be cut at these locations. Care must be taken to maintain the proper bending radii in the loop. Excess cable will also be maintained at splice locations to facilitate splicing. Normally 5% excess cable is stored during the cable placement process. Excess cable loops are not used on coaxial cable.

2.5 Installing Cable Grips

The end of the cable that is pushed into cable grips should be prepared prior to placing the cable grip onto the cable. This should be done to prevent the separating of the jacket from the internal cable components.

Coaxial Cable

Coaxial cable should be prepared by removing the jacket from a section of cable about half the length of the cable grip. The cable should not protrude from the grip.

Fiber Optic Cable

Pulling grips are installed on the fiber optic cable. Typical grips include a Kellums® or crimp-on grip.

Refer to the cable manufacturers recommendation for grip installation. Proper grip installation is a function of cable design and grip type. The concept of the grip is to evenly distribute the tensile load to all elements of the cable. Typically, the strength members of the cable (kevlar®, or stainless steel wires) should be formed around the eye of the pulling grip. If the grip is installed improperly, the grip will release prior to the maximum allowable pulling tension being reached or it may damage the fiber optic cable.

2.6 Tension on Cables During Lashing

Tension that is applied to cables during the lashing process should be minimal. Tension is often applied during lashing to make the cable lash uniformly to the strand. Applying tension to the cable while lashing creates undesirable tension in optical waveguide. This practice also puts coaxial cable under stress. Ideally cables should not be stressed during lashing. Proper spacing of cable blocks will minimize the tension on cables as the cables enter the lasher when using the back-pull method of construction.

2.7 Lasher Selection

The choice of lasher should be considered prior to the start of lashing. Improper lasher selection may cause the lasher to scrape along the cable or cable bundle. Considerations should be made of the cable bundle size being lashed and the size of the strand. Lashers have internal strand rollers designed for particular strand sizes.

2.8 Fiber Optic Cable Lengths

It is preferable to avoid putting splices into fiber optic cable therefore fiber optic cables are manufactured in extremely long lengths. These long lengths often make it impossible to install the full length of cable in one pull because of the accumulation of tension along the cable route. When pulling tension reaches the maximum allowed, the tension must be relieved from the cable in the pull route.

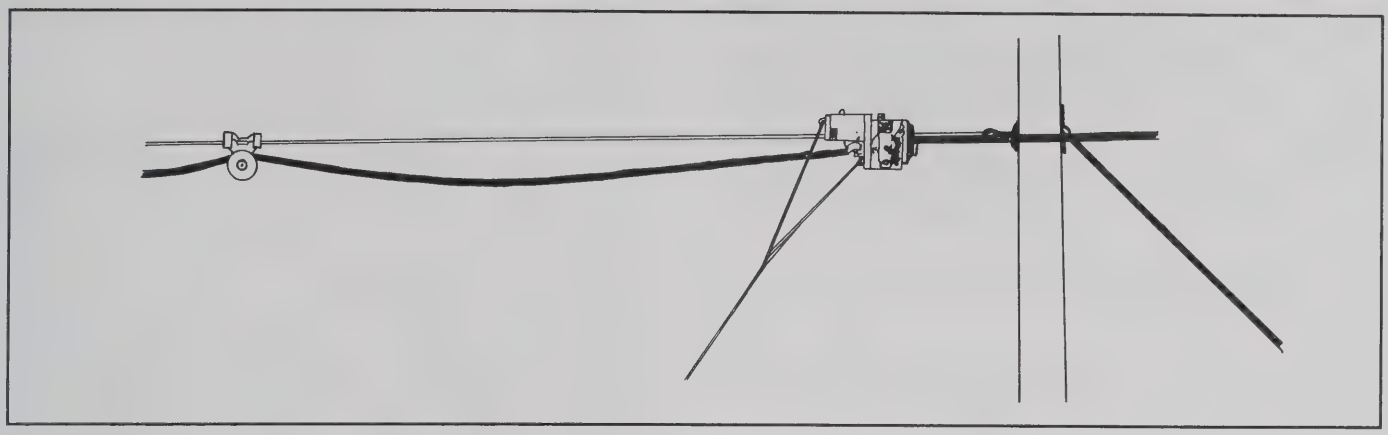


Figure 9.1: Lashing Cables, Back-Pull Method

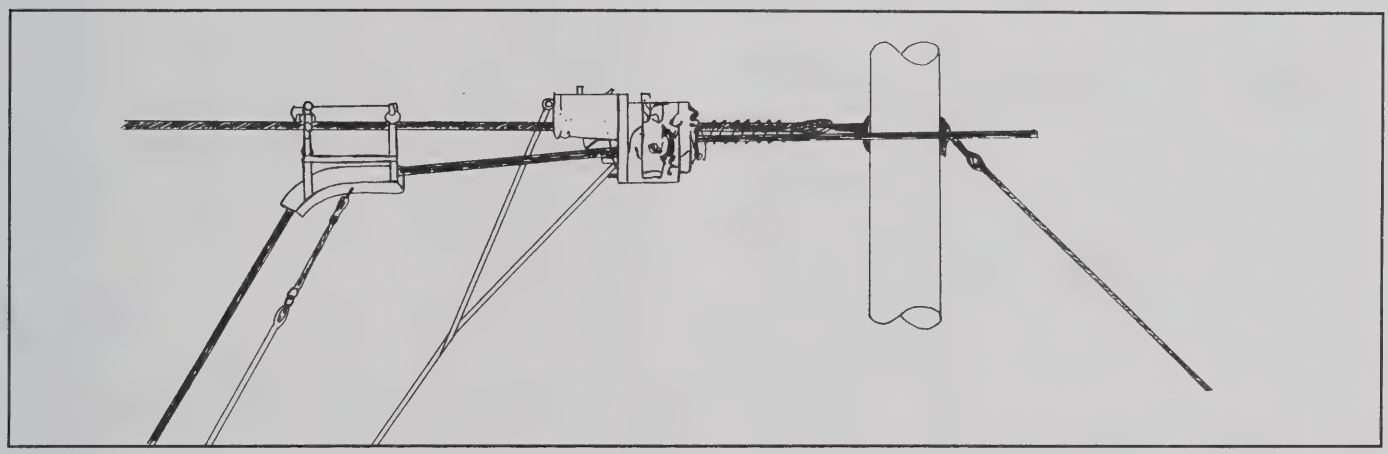


Figure 9.2: Lashing Cables, Drive-Off Method

The tension is relieved by using intermediate assist devices or by "figure-eighting" the cable. Intermediate assist devices can be a series of mechanical winches or capstan drives interconnected with a master controller. These devices can also be as simple as having craftsmen assist the cable by hand.

Figure-eighting is another technique used if mechanical devices are not available. In this application, the cable is carefully arranged on the ground in a figure-eight pattern. Usually traffic cones are used to establish a figure-eight pattern.

When laying down the figure-eight, care should be taken not to tangle the cable. This also applies when completing the cable placement process. It may be necessary to turn the figure-eight over. This is done by carefully "walking" the figure-eight over.

3.0 Aerial Cable Placement on New Strand

Circumstances at the construction site, equipment availability and manpower availability will dictate which placement method will be used. The back-pull method is the usual method of cable placement.

Drive-off methods may be employed to realize some manpower and time savings in the cable placement and lash-up when appropriate.

3.1 Back-pull method

Figure 9.3: Back-Pull Cable Placement Methods, Lashed Cable; should be reviewed in conjunction with the following procedures.

Trailer set-up

- The trailer should be positioned in-line with the strand approximately twice the height of the hardware attachments from the set-up chute. If the trailer cannot be positioned in-line with strand route, the set-up chute and cable trailer should be aligned to prevent the cable from rubbing on the cable reel or binding on the set-up chute.
- Wheels of the trailer should be chocked.
- The cable should pay-off the top of the cable reel. The pay-off of the cable from the reel should cause a downward force at the hitch of the trailer.
- Reel brakes should be adjusted as needed.

Set-up chute placement

- The set-up chute should be positioned on the first pole of the cable route or attached to the strand at the first pole. Placement of the set-up chute should keep the cable from rubbing on the reel, pole, or causing undue friction on the set-up chute. A 45 degree corner block may be used as a set-up chute.

Cable puller set-up

- An appropriate cable grip should be placed on each cable.
- A break-away swivel should be placed between the pulling grip and the cable puller.
- An in-line dynamometer may be placed between the pulling grip and cable puller.
- The cable puller should be placed on the strand and the puller gates closed to secure the puller to the strand.
- A pulling line will be attached to the cable puller.
- The cable will be pulled out along the strand and cable blocks placed to support the cable as the cable is pulled. The cable puller has an internal strand brake to prevent the tension in the cable from pulling the cable puller backward on the strand when the pulling tension is released.

Cable block placement

- Cable blocks should be placed on the strand at approximately 30 to 50 foot intervals.
- A cable lifter should be used to lift cables into cable blocks as needed.
- Corner blocks should be placed at all corners greater than 45 degrees in the pole line. At corners less than 45 degrees, cable blocks can be placed on the strand several feet from and on each side of the pole-line hardware. The cable blocks should allow the cable to move through the corner without undue bending or drag.

Passing the cable puller at poles

The cable puller will have to be detached from the strand and passed across pole-line hardware by linemen.

- The cable puller should be pulled to the pole. Tension in the pulling line can be released. A lineman will pull the cable across the pole face and attach the cable puller back to the strand. Some assistance may be given by the groundman in pulling the cable across the face of the pole. Under direction of the lineman, the groundman can apply tension to the pulling line and pull the cable across the face of the pole after the lineman removes the cable puller from the strand. The cable puller strand brake will keep the cable from pulling back across the face of the pole after it is attached to the strand. The pull can be continued.
- Cable blocks should be placed at the pole.
- At corner block locations, a lineman will pass the cable puller to the opposite side of the pole and route the cables through the corner block as done at other pole hardware.

Power Winching Methods

A pull line can be pulled into the block system in place of the cables. This method is often used when the pole-line is obstructed or is in extremely rough terrain. The cables are winched into place using the pull line.

- The pull line should be tensioned.
- Reel brakes should be adjusted to prevent undue tension in the cables.
- Real time tension monitoring is required.
- Intermediate cable handling may be required as the pulling grips approach cable blocks and corner blocks. Radio communication between the lineman observing the pull-out and the winch operator is required.

Lashing

Lashing can start immediately after the cable pull is completed. Tools and equipment should be changed and checked. Lash-up should start at the end of the cable pull. The lasher will be pulled toward the cable reel.

Lashing wire clamps will be secured to the strand at the appropriate locations. Note that the location of the lashing wire clamp varies with equipment and expansion loop configurations.

Lashing wire preparation at lashing wire clamps varies. A common practice is to cut the lashing wire from the lasher, wrap the lashing wire twice around the strand in the same direction as the twist in the strand, and in the lay of the strand. Pass the lashing wire between the washers of the lashing wire without overlapping the wire. See **Figure 9.5: Lashing Wire Clamp Preparation**. The wire will then be wrapped around the clamp to the post on the opposite side of the clamp and wrapped twice around the post. The wire will be cut and tucked between the halves of the lashing wire clamp. The washers will be pressed together when the nut is tightened with a nut driver. Bands and spacers will be installed as required.

The following itemization of tasks and concerns are specific to lashing coaxial and fiber optic cables.

Coaxial Cable

- A cable positioner may optionally be arranged ahead of the lasher to position the cables that enter the lasher.

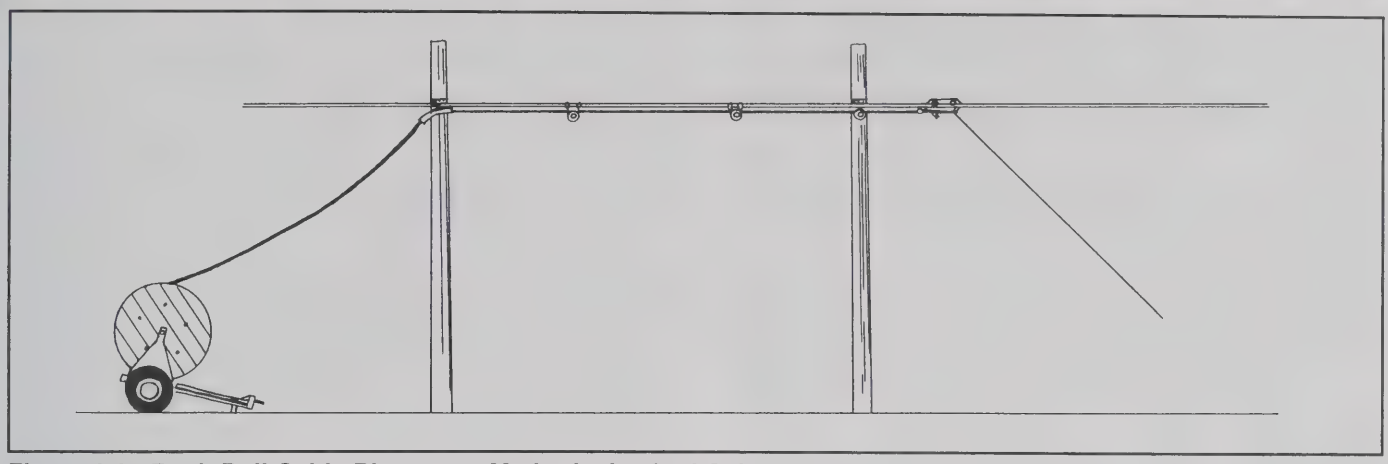


Figure 9.3: Back-Pull Cable Placement Methods, Lashed Cable

- A length of coaxial cable, i.e., a tail, should be left at all splicing locations. The length of the cable tail is dependent on the splicing that must be done at this location. Design schematics should be reviewed to determine the length of tail that is required. It is typical to pull a cable tail across the face of the pole to 48 inches on the opposite side of the pole. This practice eliminates errors related to cable tail lengths. The end of the cable should be capped and loosely tied to the strand.
- A lashing wire clamp should be properly positioned and the lashing wire secured to the clamp. Lashing should not be started until the proper cable tails are prepared, expansion loops are formed, or the cable is formed around hardware as needed. If expansion loops are made in the cable, the expansion loop bender should be kept inside of the loop as the lasher is started down the span. The bender should not be removed until the entire span is lashed. Tension in the cable caused by the lasher may cause the loop to be deformed.
- Coaxial cable should not be tight-lashed.
- As the lasher approaches cable blocks, the cable blocks should be removed from in front of the lasher with a cable block lifter or the cable blocks may be pushed to the next pole by utilizing a cable block pusher. It is important to minimize the tension on cables as they enter the lasher. This is done by leaving the cable blocks in place until the lasher is adequately close to support the cable.
- A lineman should remove the cable blocks from in front of the lasher and from the pole as the lasher is pulled to a pole to prevent the lasher from binding the cable blocks.

A lineman must pass the lasher across the pole-face to the strand and cable on the opposite side of the pole at all poles.

- The lasher cannot be pulled backward along the strand while the gates to the lasher are closed. The lineman will cut the lashing wire from the lasher and secure the lashing wire to a lashing wire clamp while ensuring that the lashing wire is not allowed to loosen from around the cable.
- The lasher gates should be opened. The lineman should pass the lasher across the pole-face and set the lasher on the strand on the opposite side of the pole. The cables should be pushed into the lasher and the gates closed.
- Lashing should continue until reaching the cable reel. Some special considerations may need to be made at the set-up pole depending on the equipment configuration.
- The cable reel should be rotated to take up any excess slack that develops when lashing cables.

Fiber Optic Cables

- An excess fiber cable loop will be made at the first pole of the lash-up to facilitate splicing. The length of excess fiber should be sufficient to reach the ground, enter into a splicing trailer or truck and be spliced into an enclosure.
- A cable positioner may optionally be arranged ahead of the lasher to position the cables that enter the lasher.
- A lashing wire clamp will be positioned and the lashing wire secured to the lashing wire clamp. Fiber optic cable should not be tight-lashed with coaxial cable. The lasher will be set-up and pulled outward from the pole.
- As the lasher approaches cable blocks, they should be removed from in front of the lasher with a cable block lifter, or the cable blocks may be pushed to the next pole by utilizing a cable block pusher. Note that it is important to minimize the tension on cables. This is done by leaving the cable blocks in place until the lasher is adequately close to support the cable.

- A lineman should remove the cable blocks from in front of the lasher and from the pole as the lasher is pulled to a pole to prevent the lasher from binding the cable blocks.

A lineman must pass the lasher across the pole-face to the strand and cable on the opposite side of the pole at all poles.

- The lasher cannot be pulled backward along the strand while the gates to the lasher are closed. The lineman will cut the lashing wire from the lasher and secure the lashing wire to a lashing wire clamp while ensuring that the lashing wire is not allowed to loosen from around the cable.
- The lasher gates should be opened. The lineman should pass the lasher across the pole-face and set the lasher on the strand on the opposite side of the pole. The cables should be pushed into the lasher and the gates closed.
- A lashing wire clamp should be properly positioned and the lashing wire secured to the clamp. Lashing should not be started until the proper loop at the clamp is made or excess cable is looped at the location as needed.
- Lashing should continue until reaching the cable reel. Some special considerations may need to be made at the set-up pole depending on the equipment configuration.
- The cable reel should be rotated to take up excess slack that develops at the reel as the cable is lashed back toward the trailer.

3.2 Drive-off method

Figure 9.4: Drive-Off Cable Placement Methods, Lashed Cable; should be reviewed in conjunction with the following procedures.

Trailer set-up

- The cable should pay-off the top of the cable reel and to the rear of the cable trailer.
- Reel braking should be minimal.

Set-up chute placement

- The set-up chute should trail sufficiently behind the trailer to prevent the cable from binding on the set-up chute.
- The set-up chute will be positioned in front of the lasher as seen in **Figure 9.2: Lashing Cables, Drive-Off Method**. The set-up chute may be attached directly to the lasher dependent on chute and lasher type.
- The cable should move through the chute and only contact the chute section. If the pole-line is offset from the reel, close observation must be made of the cable moving through the chute. Off-set of the cable reel from the set-up chute may cause the cable on the reel to drag on the reel flange and the cable in the chute to bind on the chute.

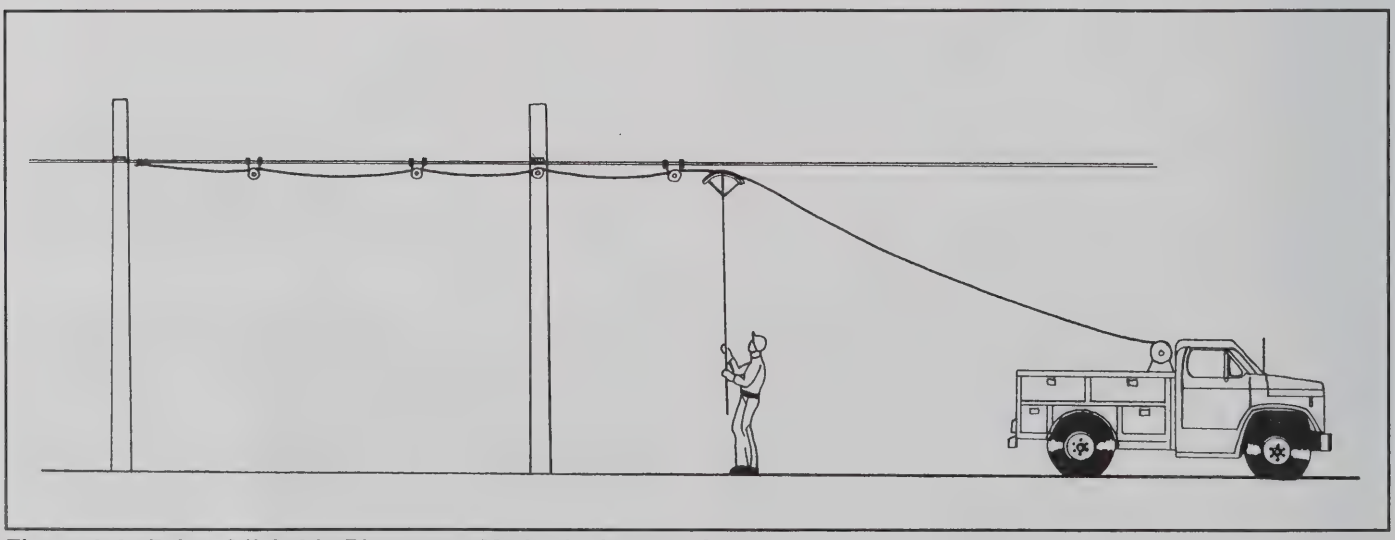


Figure 9.4: Drive-Off Cable Placement Methods, Lashed Cable

Lashing

Lashing wire clamps will be secured to the strand at the appropriate locations. Note that the location of the lashing wire clamp varies with equipment and expansion loop configurations.

Lashing wire preparation at lashing wire clamps varies. A common practice is to cut the lashing wire from the lasher, wrap the lashing wire twice around the strand in the same direction as the twist in the strand and in the lay of the strand. Pass the lashing wire between the washers of the lashing wire without overlapping the wire. See **Figure 9.5: Lashing Wire Clamp Preparation.** The wire will then be wrapped around the clamp to the post on the opposite side of the clamp and wrapped twice around the post. The wire will be cut and tucked between the halves of the lashing wire clamp. The washers will be pressed together when the nut is tightened with a nut driver. Bands and spacers will be installed as required.

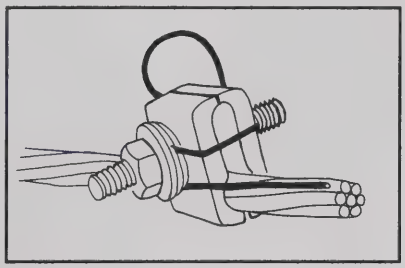


Figure 9.5: Lashing Wire Clamp Preparation

Coaxial Cable

- A length of coaxial cable, i.e., a cable tail, should be left at all splicing locations. The length of the cable tail is dependent on the splicing configuration done at each location. Design schematics should be reviewed to determine the length of cable tail that is required. It is typical to pull a cable tail across the face of the pole to 48 inches on the opposite side of the pole.This practice eliminates errors related to cable tail lengths. The end of the cable should be capped and loosely tied to the strand.
- A lashing wire clamp should be properly positioned and the lashing wire secured to the clamp. Lashing should not be started until the proper cable tails are prepared, expansion loops formed, and the cable is formed around hardware as needed. If expansion loops are made in the cable, the expansion loop bender should be kept inside of the loop as the lasher is started down the span. The bender should not be removed until the entire span is lashed. Tension in the cable caused by the lasher may cause the loop to be deformed.

A lineman will pass the lasher and set-up chute across the pole-face as the lasher encounters poles in the cable route.

- Tension should be released from the set-up chute pull line to allow the removal of the set-up chute from the strand. The set up chute will be placed on the strand on the opposite side of the pole.
- The cables will be placed in the set-up chute.
- The set-up chute will be pulled outward from the pole to allow space for the lasher to be placed on the strand.
- Tension should be released from the lasher pull line. The lashing wire will be secured to a lashing wire clamp. The lasher will be moved across the face of the pole.
- Lashing wire will be pulled from the lasher and secured to a lashing wire clamp. Lashing should not be started until the proper cable tails are prepared, expansion loops formed and the cable formed around hardware as needed.
- Lashing will continue in this manner until cable placement is complete.

Fiber Optic Cable

- An excess fiber cable loop will be made at the first pole of the lash-up to facilitate splicing.
- A lashing wire clamp should be properly positioned and the lashing wire secured to the clamp.
- Excess cable loops will be placed as needed in the fiber route.
- As the lasher and set-up chute reaches a pole, a lineman must pass the lasher across the pole face.
- Tension should be released from the set-up chute pull line to allow the removal of the set-up chute from the strand. The set up chute will be placed on the strand on the opposite side of the pole.
- The cables will be placed in the set-up chute.
- The set-up chute will be pulled outward from the pole to allow space for the lasher to be placed on the strand.
- Tension will be released from the lasher pull line. The lashing wire will be secured to a lashing wire clamp. The lasher will be moved across the face of the pole. The lashing wire will be pulled from the lasher and secured to a lashing wire clamp. Lashing should not be started until cable is formed around hardware as needed.
- Lashing will continue in this manner until cable placement is complete.

4.0 Overlash Cable Placement

Overlashing cables onto existing cable plant is accomplished in much the same manner as installing cable onto new strand. Unique aspects of overlash cable placement are reviewed in this subsection.

- Loading of the strand by an additional cable must be considered. Sag and tension analyses should be done to account for the additional cables added to the cable bundle.
- Overlash cable pullers should be used to pull cables into place. Attention will have to be continuously given to the pulling line tension of the overlash cable puller. Tension must be maintained at all times on the pulling line. Overlash cable pullers do not have a strand brake and will be pulled backward on the span by the tension in the cables being pulled.
- Pole-line hardware configurations common to lashed cable construction as seen in **Section 11** are used. All guys and anchors should be installed and tensioned prior to the cable placement task.
- Specialized suspension clamps are available for locations where the cable will not be separated from the support messenger.
- Cable blocks can only be positioned at poles. The cable blocks are attached to the pole hardware dependent on the type of cable block used.

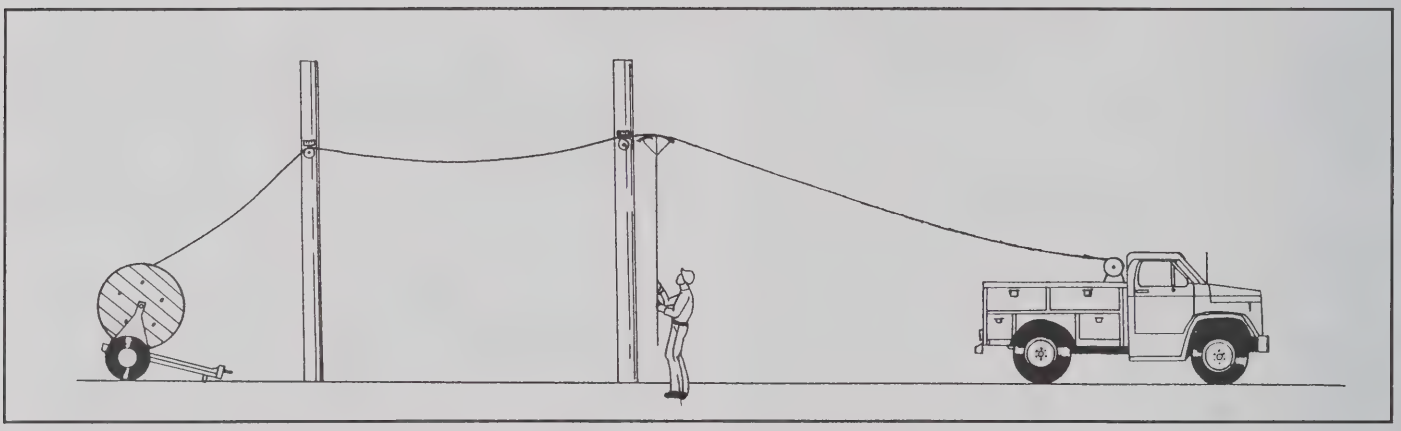


Figure 9.6: Back-Pull Cable Placement Methods, Integrated Messenger Cable

- Cable blocks designed specifically for overlash applications should be placed onto the cable bundle with a cable block lifter and the cable lifted into the cable block with a cable lifter. During lashing the cable blocks must be removed from the cable bundle with a cable block lifter. Pushing the cable blocks in front of the lasher may damage existing cables.
- Bands and spacers must be removed from the existing cable bundle during lash-up. New bands and spacers will be installed to bundle all cables.

5.0 Integrated Messenger Cable Placement

Time savings in cable placement can be realized using integrated messenger cables. Often a one man crew can place integrated messenger cable. Integrated messenger cables are recommended to be used only on short cable lengths, associated construction equipment, construction equipment configurations and stress placed on the cable limits the practical lengths of integrated messenger cable that should be installed. Back-pull and drive-off cable placement methods are used for placement of integrated messenger cables.

Integrated messenger cables are also referred to as IM cables, figure-eight cables, or self-support cables.

Unique aspects of IM cable placement are reviewed in this subsection.

- Coaxial cable expansion loops can only be placed in IM cables where there is equipment to be spliced or where the messenger is cut.
- Insulated gloves should be worn by all personnel that are in contact with the cable and messenger that is being pulled into place. Insulated gloves should be worn until the messenger is bonded to the grounding network. Care should be taken to ensure that the messenger or cable is not directly contacted by construction personnel. Routine inspection and certified testing of insulated gloves is required.

5.1 Back-pull (Stationary Reel) Method

Installation of a traveling ground onto the messenger of an IM cable is impractical. Safe placement of this cable type by the back-pull method must be critically reviewed. The presence of power conductors must be considered when pulling an ungrounded cable. **Figure 9.6: Back-Pull Cable Placement Method, Integrated Messenger Cable**; should be reviewed in conjunction with the following procedures.

Trailer set-up

- The trailer should be positioned in-line with the strand approximately twice the height of the hardware attachments from the set-up chute. If the trailer cannot be positioned in-line with strand route, the set-up chute and cable trailer should be aligned to prevent the cable

from rubbing on the reel or pole, or causing undue friction on the set-up chute.

- Wheels of the trailer should be chocked.
- The cable should pay-off the top of the cable reel. The pay-off of the cable from the reel should cause a downward force at the hitch of the trailer.
- Reel brakes should be adjusted as needed.

Set-up chute placement

- The set-up chute should be positioned on the first pole of the cable route. Placement of the set-up chute should keep the cable from rubbing on the reel or pole, or causing undue friction on the set-up chute.

Cable puller set-up

- An appropriate strand grip can be used to pull the cable. Attention should be given to the tension that is being placed on the cable. There is not a practical method to monitor the tension in the cable itself.
- A pulling line will be attached to the integrated messenger.
- A automatic tension relief device should be used if the IM cable is pulled with a vehicle.

Cable block placement

- The cable will be pulled out along the pole line and lifted into the cable blocks with a cable lifter.
- The force of the cable on the cable block is an outstanding concern. Sufficient pressure on the cable will deform the cable conductor concentricity in coaxial cable or cause undue bending in fiber optic cable.

Tensioning the cable

- The cable will be tensioned with a hoist and strand grip at all dead-end hardware configurations. Bonding and grounding should be completed when the cable is tensioned.
- The cable will be lifted from the cable blocks and placed in the suspension clamps after tension is placed on the messenger at the dead-end hardware configurations.
- Bonding and grounding at suspension clamps should be completed when the messenger is placed in the suspension clamps.

5.2 Drive-off (Moving Reel) Method

Drive-off methods for placing IM are the simplest of cable placement methods. See **Figure 9.7: Drive-off Cable Placement Methods, Integrated Messenger Cable.**

- The messenger should be attached to pole-line hardware at the first pole of the cable run.
- The messenger should be grounded and bonded at the first pole when using the drive off method.
- Cable blocks should be installed at all poles not framed in dead-end hardware configurations.
- The cable should pay-off the top of the reel and be lifted into the cable block with a cable lifter.
- Pay-off should be slow and uniform to prevent uneven tension from being applied to the IM cable.
- The cable should be tensioned at locations with dead-end hardware configurations. Bonding and grounding should be completed at this location when the cable is tensioned.
- The cable will be lifted from the cable blocks and placed into the suspension clamp when the cable route has been tensioned. Bonding and grounding at the suspension clamp should be completed when the messenger is placed in the suspension clamps.

6.0 Prelashing Cable Placement Methods

Prelash cable placement methods are not recommended.

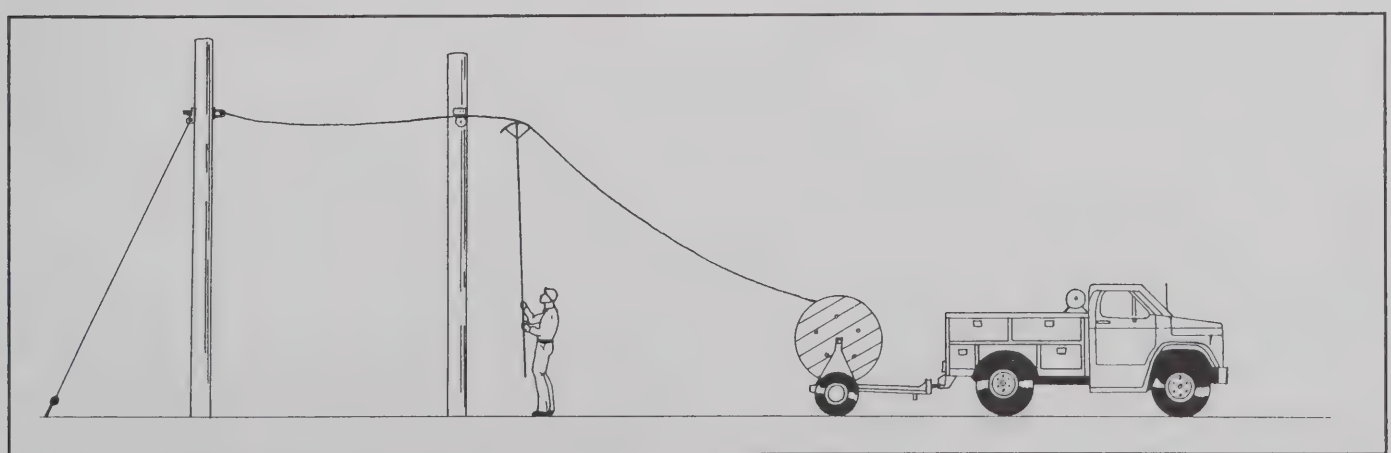


Figure 9.7: Drive-Off Cable Placement Methods, Integrated Messenger Cable

Subsurface Cable Construction

1.0 General

2.0 Subsurface Cable Placement Concerns
- 2.1 Pulling Tensions
- 2.2 Bending Radii
- 2.3 Expansion Loops
- 2.4 Excess Cable Loops, Fiber Optic Cable
- 2.5 Installing Cable Grips
- 2.6 Fiber Optic Cable Lengths
- 2.7 Locating Subsurface Property
- 2.8 Open Trenches and Pits
- 2.9 Cable Selection
- 2.10 Conduit and Duct Placement

3.0 Direct Buried Cable Placement
- 3.1 Boring
- 3.2 Trenching
- 3.3 Plowing

4.0 Installing Cable in Duct

1.0 General

Subsurface cables are divided into two major categories. The categories are referred to as underground cable systems and direct buried cable systems.

Underground cable systems are those systems that interconnect manholes and vaults. The cables of underground systems are normally connected via a duct system that is constructed as part of a civil engineering project. The construction of the duct system is beyond the scope of this manual and accordingly will not be reviewed. Placement of cables into underground duct systems will be reviewed.

Direct buried cable systems are constructed by trenching or plowing cables or cable conduits into the earth. Trenching and plowing methods will be reviewed.

Occupational Safety and Health Administration (OSHA) guidelines for excavation and tunneling should be reviewed and followed.

2.0 Subsurface Cable Placement Concerns

Concerns related in subsections 2.0 - 2.8 are common to all subsurface coaxial cable and fiber optic cable placement techniques.

2.1 Pulling Tension

Cables are pulled into place by applying force to the end of the cable. Excessive forces applied to the cables will cause the cables to permanently elongate. Permanent elongation of fiber optic cable may damage the optical waveguide by fracturing the glass. Deformations of the conductor geometry causes an impedance change in coaxial cable and also causes difficulty when installing connectors.

Pulling tension for all cable types are specified in the CommScope product catalogs. AT NO TIME SHOULD THE MAXIMUM PULLING TENSIONS BE EXCEEDED. Good construction techniques and proper tension monitoring equipment are essential.

Break-away Swivels

Break-away swivels should be placed on pulled cables to ensure that the maximum allowable tension for that specific cable type is not exceeded. The swivel is placed between the pull line and the pulling grip. A break-away swivel is required for each cable when pulling multiple cables.

Tail Loading

Tail loading is the tension in the cable caused by the mass of the cable on the reel and reel brakes. Tail loading is controlled by two methods. It can be minimized by using minimal braking during the pay-off of the cable from the reel. At times no braking is preferred. Tail loading can also be minimized by rotating the reel in the direction of pay-off.

2.2 Bending Radii

Cables are often routed through corners during cable placement. As cables are routed through the corners, pulling tension must be increased to apply adequate force to the cable to bend the cable around the corner. Tension that must be applied to the cable to pull the cable around the corner is directly related to the flexibility of cable. Flexibility is a function of cable size and design.

The static bending radius of coaxial cable (minimum bending radius as specified in the CommScope product catalog) is the minimum radius that a cable can be formed without electrical or mechanical degradation of the cable. Bending the cable in this manner is usually only done during splicing or final forming of the cable.

The radius of the bend in the cable as the cable is being pulled is the dynamic bending radius. The minimum bending radius of cable as specified in the CommScope coaxial cable product catalog is the static bending radius of the cable, i.e., the minimum bending radius when the cable is not loaded.

Bending radii for fiber optic cables are given in loaded and unloaded conditions. Always review the specifications for the appropriate bend radii. Loaded means that the cable is under the maximum allowable pulling tension and is being bent simultaneously. Unloaded means that the cable is under no tension. Unloaded conditions occur at splice points, hand holes, vaults, or other termination points. The unloaded bending radius is the radius allowed for storage purposes.

The dynamic bending radii of cables during the construction process are controlled by construction techniques and construction equipment. Conduit bends, cable sheaves, plow shares and cable shoes should have large radius bends and low friction surfaces that minimally contribute to the increase in pulling tension that is required to pull the cable through this equipment.

2.3 Expansion Loops

Expansion loops are not required for subsurface coaxial and fiber optic applications.

2.4 Excess (Slack) Cable Loops, Fiber Optic Cable

Excess (slack) cable is installed at locations where there might be a relocation of equipment enclosures or a change of right-of-way associated with subsurface plant. The cable will not be cut at these locations.

Excess cable should also be maintained at splice locations to facilitate splicing. Normally 5% excess cable is stored during the cable placement process. Excess cable loops are not used on coaxial cable.

2.5 Installing Cable Grips

The end of the cable that is pushed into cable grips should be prepared prior to placing the cable grip onto the cable. This should be done to prevent the separating of the jacket from the internal cable components.

Coaxial Cable

Coaxial cable should be prepared by removing the jacket from a section of cable about half the length of the cable grip. The cable should not protrude from the grip.

Fiber Optic Cable

Pulling grips are installed on the fiber optic cable. Typical grips include a Kellums® or crimp-on grip.

Refer to the cable manufacturers recommendation for grip installation. Proper grip installation is a function of cable design and grip type. The concept of the grip is to evenly distribute the tensile load to all elements of the cable. Typically, the strength members of the cable (kevlar®, or stainless steel wires) should be formed around the eye of the pulling grip. If the grip is installed improperly, the grip will release prior to the maximum allowable pulling tension being reached or it may damage the fiber optic cable.

2.6 Fiber Optic Cable Lengths

It is preferable to avoid putting splices into fiber optic cable therefore fiber optic cables are manufactured in extremely long lengths. These long lengths often make it impossible to install the full length of cable in one pull because of the accumulation of tension along the cable route. When pulling tension reaches the maximum allowed, the tension must be relieved from the cable in the pull route.

The tension is relieved by using intermediate assist devices or by "figure-eighting" the cable. Intermediate assist devices can be a series of mechanical winches or capstan drives interconnected with a master controller. These devices can also be as simple as having craftsmen assist the cable by hand.

Figure-eighting is another technique used if mechanical devices are not available. In this application, the cable is carefully arranged on the ground in a figure eight pattern. Usually traffic cones are used to establish a figure-eight pattern.

When laying down the figure-eight, care should be taken not to tangle the cable. This also applies when completing the cable placement process. It may be necessary to turn the figure-eight over. This is done by carefully "walking" the figure-eight over.

2.7 Locating Subsurface Utilities

Broadband and CATV cable construction is typically done within right-of-way dedicated for the routing of municipal and utility pipes, wires, cables and conduits. Excavation within any right-of-way will often reveal a multitude of underground infrastructures. The integrity of existing subsurface plant must be ensured during any excavation activity. Damage to one of these utilities may cause a disruption of services provided by the owner of the pipe, wire, cable or conduit, or may cause catastrophic harm to the excavating party and surrounding property.

Subsurface plant operators should be contacted prior to the start of any excavation. The contact of subsurface plant operators is normally required by law. Contact should be made for all excavations, including those that are out of the right-of-way. The plant operator will indicate the vertical location of their plant with a flag or paint mark. The flag or paint mark is commonly called a locate mark. There are typically laws that require the subsurface plant owner to locate their respective plant within a defined time period and to ensure that the locate mark is correctly positioned. The recovery of damages resulting from excavation work is generally decided with high consideration given to the locate marks. The primary intent of the locate is to PREVENT damage to existing plant, not to define liability.

Subsurface plant locators are electronic transmitters and receivers. The transmitter will couple a signal onto the plant at an accessible location and the receiver will be used to detect the electric field emitted from plant along the length of the plant. Depth and vertical location of the plant can be established. Electronic locators only work on conductive pipes, wires, cables or conduits.

The owner of the real estate should also be contacted prior to excavation. There may be water sprinkler, closed circuit television or communication systems buried in or around the right-of-way. The excavating party should also make necessary locates on their existing plant.

2.8 Open Trenches and Pits

Subsurface excavation locations are rarely inaccessible to the public. The danger and liability of open trenches and pits must be of high concern. Barricades, warning devices and covers should be used anytime a trench or pit is left unattended.

2.9 Cable Selection

Coaxial cable placed directly in the ground or in conduit systems will be manufactured specifically for this application. Subsurface coaxial cables typically have a plastic jacket and a viscous flooding compound between the jacket and the outer conductor. Jacket enhancements and armored jackets are available. Fiber optic cables are manufactured for direct burial or placement in conduit systems.

2.10 Conduit and Duct Placement

Conduit and duct systems are used to protect cables from objects that might be present in the trench line or plow line. These objects may be of concern during trench excavation or plowing, or they may be of long term concern due to frost heave or ground movement. Conduit and duct systems are also used to provide some flexibility in pulling cables into place or making repairs to cables that exist inside the duct system.

3.0 Direct Buried Cable Placement

Direct burial of cable or conduits is usually accomplished by an assortment of placement methods. The circumstances that exist at the construction location will partially dictate the method used. Availability of manpower and equipment will further dictate the construction method. Methods of excavation particular to special construction circumstances will not be reviewed in this manual.

3.1 Boring

Conventional Bores

Routing of cables and conduits may necessitate the subsurface crossing of streets, parking lots or other immovable objects. A mechanical boring machine may be utilized to push a drill stem the length of the crossing. Pneumatically driven pistons are also used to complete subsurface crossings.

Subsurface crossings are generally accomplished by digging an excavation pit (trench) on each side of the crossing to allow the guiding and retrieval of the drill stem or pneumatic piston. Detailed equipment operation and excavation procedures are specified by the construction equipment manufacturer.

The tunnel of the crossing may be enlarged by using reamers. Conduits should be placed to support the tunnel wall and allow placement of cables within the crossings. Subsurface bores are often completed substantially prior to any cable placement.

Directional Bores

Directional boring is accomplished by using a steerable drill stem. The depth and direction of the boring can be controlled by the equipment operator. Substantially long bore lengths can be accomplished by using directional boring devices.

3.2 Trenching

Excavation of the earth is fundamental to placing a subsurface cable in trenches. Trenching is advantageous to the placement of several cables in one operation and for placement of cables of long lengths. Trenching is accomplished using tractors equipped with trenching chains that travel on a trenching bar. The trenches are opened (cut) by the trenching chain while the tractor provides forward movement of the trenching chain. The earth (spoil) is removed from the trench by the trenching chain and moved adjacent to the trench by a horizontal auger driven simultaneously by the tractor.

The tractor must be operated to travel a preferred path and to advance at a pace that allows the trenching chain not be excessively loaded. The tractor cannot abruptly change directions when the trencher bar is lowered into the trench. The trench route should be carefully planned and be as straight as possible. Enclosures that are offset from the primary trench should have supplemental trenches cut to the enclosure location. Bending radii of the cable/conduit should be considered when cutting the supplemental trenches.

Tractor size dictates trenching depth capability, general pace of the trench excavation and the amount of restoration work required. Larger tractors increase trench excavation rate and depth capability, but also cause greater disturbance to the area of excavation. The tractor should be of a size that can fit through the appropriate gates, cut a sufficiently deep trench, and excavate at an appropriate rate. Special trenching chains are available for rocky or frozen soil.

Construction Method

- All bores and crossings should be installed prior to the start of the trenching process.
- The trench should be excavated to a depth of 18 to 24 inches for coaxial cable and 36 to 48 inches for fiber optic cable.
- Rocks and large stones should be removed from the bottom of the trench to prevent damage to the cable due to frost heave.
- Supplemental trenches should be made to all offset enclosure locations. Trench intersections should be excavated to provide adequate space to make sweeping bends in the cable/conduit.
- Cable trailers or cable reels should be in line with the trench line to prevent any unnecessary bending of the cable. The cable should pay-off of the bottom of the reel to prevent any unnecessary bending.
- Cables and/or conduits should be pulled into place. Cables should be routed to enclosure locations leaving adequate cable lengths to allow splicing. Cables should be carefully bent around corners and bent upward at enclosure locations. Cable caps should be placed on cables as needed.
- Select back-fill (fill) should be placed into the bottom trench to provide some protection to the cables in the trench.

- Warning tape can be buried above the cable during the back-fill process.
- The trench should be filled and compacted as required. Tamping or flooding can provide compaction to prevent the trench from receding. Select fill may be required.
- Enclosures should be placed as needed.

3.3 Plowing

Cable and conduit placement by plowing methods may be faster and less intrusive than cable and conduit placement by trenching methods. Tractors provide forward movement of plowing equipment. A plow blade will split the earth and cables or conduits will be routed through and internal cavity (plow chute) to the base of the plow share. Conduit may be split and cables placed into the conduit during the plowing process. The cable and/or conduit will trail out of the base of the plow share as the tractor moves forward. The cable or conduit reel will be carried by the tractor and is spooled from the reel carriage to the plow share during placement.

Dimensions of the plow share and plow chute are governed by the dimensions of the cable and conduit being placed. The radius of the plow chute must be carefully considered with respect to cable type and the bending radius of the cable. Attention must be given to the condition of the plow chute. Burrs, sharp edges, and rough surfaces can damage cables during the placement process. Plow shares are manufactured specifically to place multiple cables simultaneously. The plow chute is divided to provide independent paths for each cable to travel through the plow.

The plowing of cable is substantially easier than plowing conduit due to the increased size of the conduit. As conduit size and placement depth increases, tractor size accordingly increases.

Two methods of plowing are associated with the underground placement of coaxial and fiber optic cables and the conduit system that may encase these cables. Vibratory and static plowing are both selectively used for cable and conduit placement. Coaxial cable is typically placed via the use of a vibratory plow. Fiber optic cable is typically placed using static plowing methods. The scale of the construction project, equipment and manpower availability, excavation specifications and the trenching environment are contributory factors that must be considered when a plowing method is selected.

Pulling coaxial or fiber optic cables behind plow shares by using a "pulling chain" or "bullet" is not recommended. The drag created by the earth on the pulled cable creates substantial tension in the cable. Unseen subsurface objects may damage the cable as the cable is pulled across the object.

Vibratory Plowing

Vibratory plowing is done utilizing a tractor with a hydraulically driven shaker that provides vibratory movement of the plow blade. The cable or conduit reel is transported by the tractor and the cable/conduit payoff is routed over the tractor body to the plow chute. See **Figure 10.1: Vibratory Plowing Method**. The vibratory plow blade will split the earth while the tractor provides forward movement of the plow blade. Cable/conduit will be routed through the plow chute and will trail the plow blade as the tractor and plow blade moves forward. There is not a means to effectively monitor pulling tension so coordinated operation of the tractor and plow are critical. Tractor size is smaller when comparing vibratory plowing to static plowing.

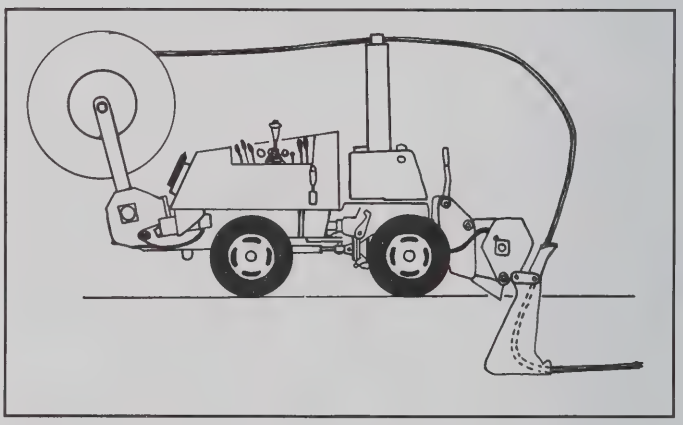


Figure 10.1: Vibratory Plowing Method

Static Plowing

Static plowing is accomplished much like vibratory plowing except the plow share does not vibrate to split the earth. Static plowing is the preferred method for installing fiber optic cables or conduit. The plow line is made by the forward movement of the tractor while the plow share is in a lowered position. See **Figure 10.2: Static Plowing Method**. The size of the plowing tractor is dictated by soil conditions and plowing depths. Soil conditions may require the use of a pre-rip tractor and/or an additional pull-piece tractor. The pre-rip tractor will spilt the soil prior to the secondary pass in the same plow line as the plowing tractor. Pull-piece tractors are used to provide additional pulling power to cable plow tractors.

Construction Method

- All bores and crossings should be installed prior to the start of the plowing process.
- Plow shares should be inspected to ensure that the bending radius of the cable is not exceeded. Plow chutes should also be inspected for burrs, sharp edges or rough surfaces.

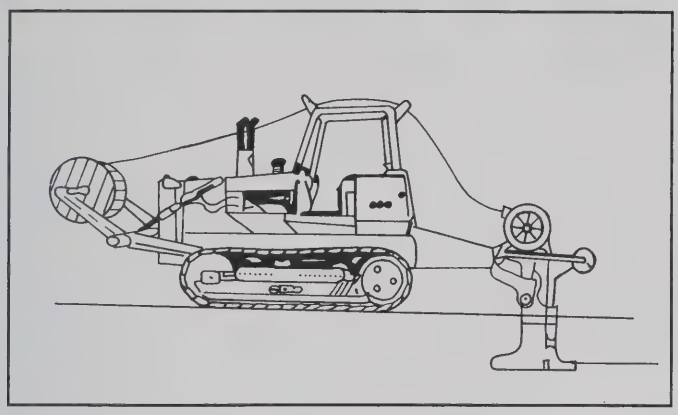


Figure 10.2: Static Plowing Method

- A trench should be excavated to enable the lowering of the plow share and forming of the cables/conduits at the start of the plow line. The specified bending radius of the cable/conduit should be considered.
- The cable reel should pay-off so as to prevent any unnecessary bending of the cable.
- Warning tape can be placed above the cable/conduit during the plowing process.
- A trench should be excavated to enable the raising of the plow share and forming of the cables/conduits at the end of the plow line. The specified bending radius of the cable/conduit should be considered.

4.0 Installing Cable in Duct

Conduits are generally placed by the aforementioned construction methods or may be existing in place. Conduits are used to facilitate the placement of extended cable lengths or maintenance of the cable after placement. Some conduits may have sub-ducts for cable management purposes. A cable route survey will dictate the cable placement scheme. The scheme must account for the difficulty of the pull, manpower and equipment availability. Intermediate assist capstans may be necessary depending on the pulling tension that develops in any length of cable. Figure-eighting of the cable may be required.

Existing duct systems generally require some maintenance prior to placing cables into the duct. A rodding machine may be used to remove unwanted debris and water from the duct. A pull line can be blown through the duct and attached to a winch line that is pulled back through the duct. The winch line will pull the cable into place. Tension monitoring and break-away swivels are recommended. Duct lubricant should be used on all cable pulls. Pay-off of the cable into the duct system should be positioned to prevent any unnecessary bending of the cable.

General Construction of Conduit Systems

- The bending radii of conduit systems should be kept sufficiently large to prevent tension due to side-wall friction from being the limiting factor of cable placement.
- Conduits should be routed in straight paths, both horizontally and vertically. Undulations in the conduit system cause increases of pulling tensions due to side-wall pressure.

Hardware and Splice Configurations

1.0 General

2.0 Poleline Hardware Configurations

3.0 Coaxial Cable Expansion Loop Configurations

4.0 Equipment Splicing Configurations

1.0 General

Hardware and splice configurations are specific to the application requirements of the cables and the circumstances found in the field. This section reviews some commonly found configurations.

2.0 Poleline Hardware Configurations

The following hardware configurations are represented in this section.

Figure 11.1: Straight Line Pole Framing Hardware
Figure 11.2: Angled Pole Framing Hardware
Figure 11.3: Mid-span Cross-over
Figure 11.4: Dead-End Framing Hardware
Figure 11.5: False Dead-End Framing Hardware
Figure 11.6: Double Dead-End Framing Hardware
Figure 11.7: Line Pole Dead-End

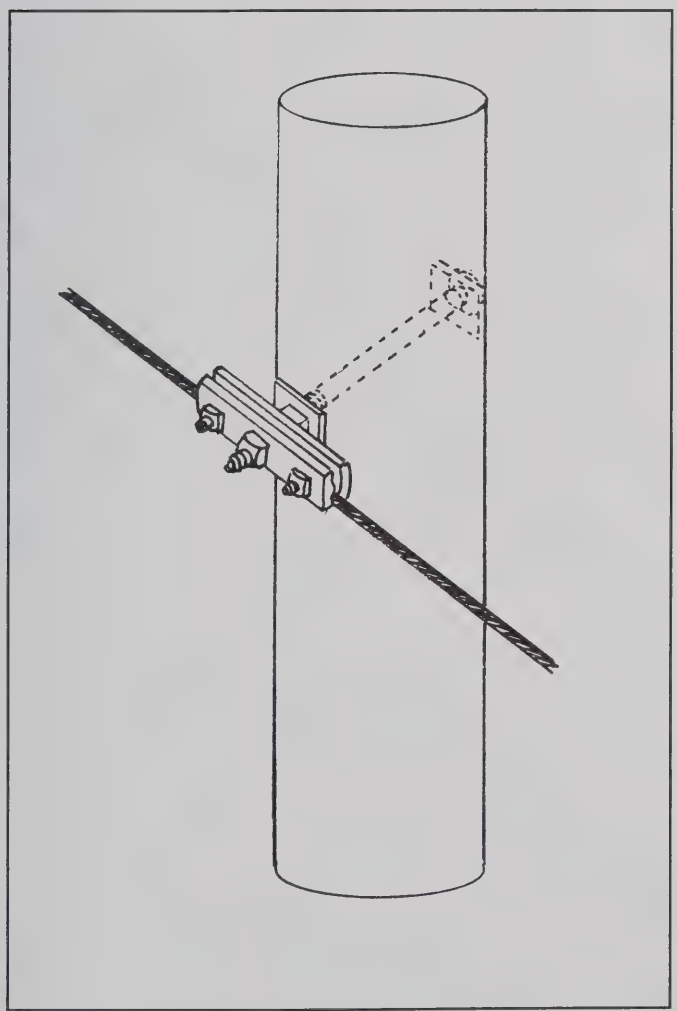


Figure 11.1: Straight Line Pole Framing Hardware

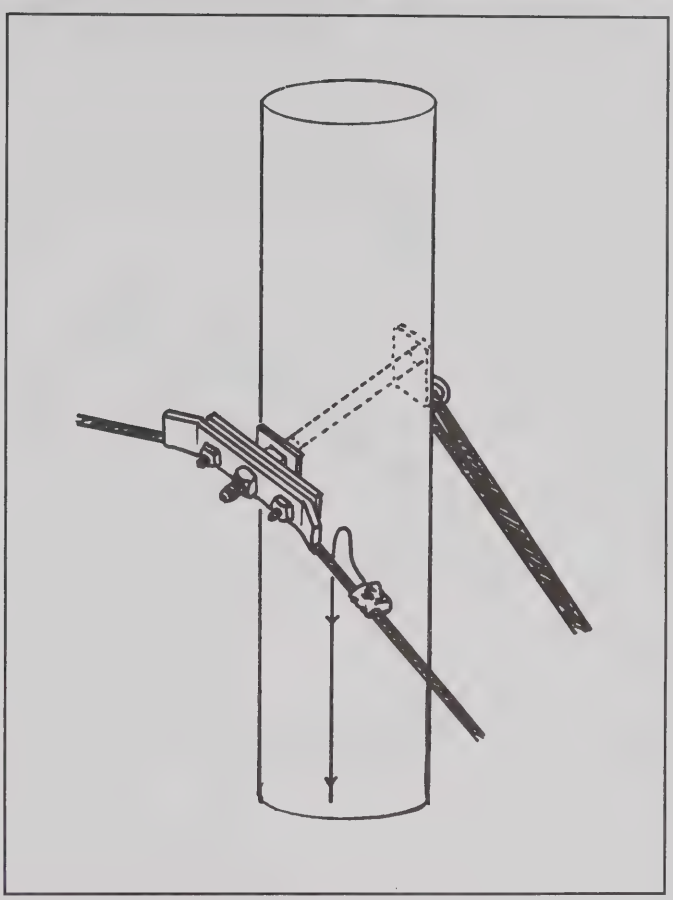


Figure 11.2: Angled Pole Framing Hardware

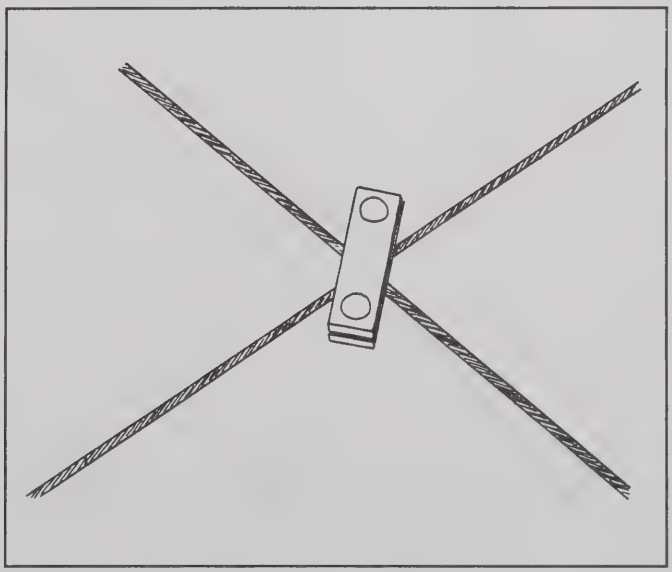


Figure 11.3: Mid-span Cross-over

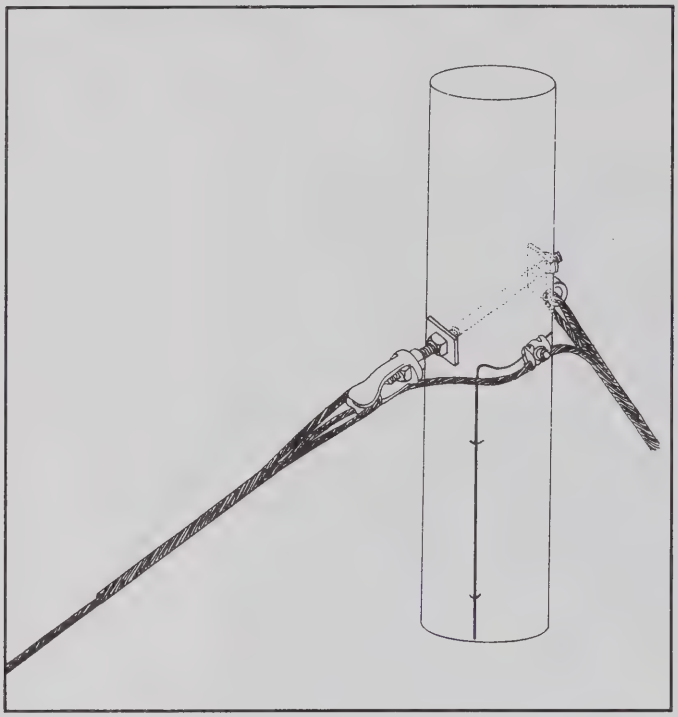


Figure 11.4: Dead-End Framing Hardware

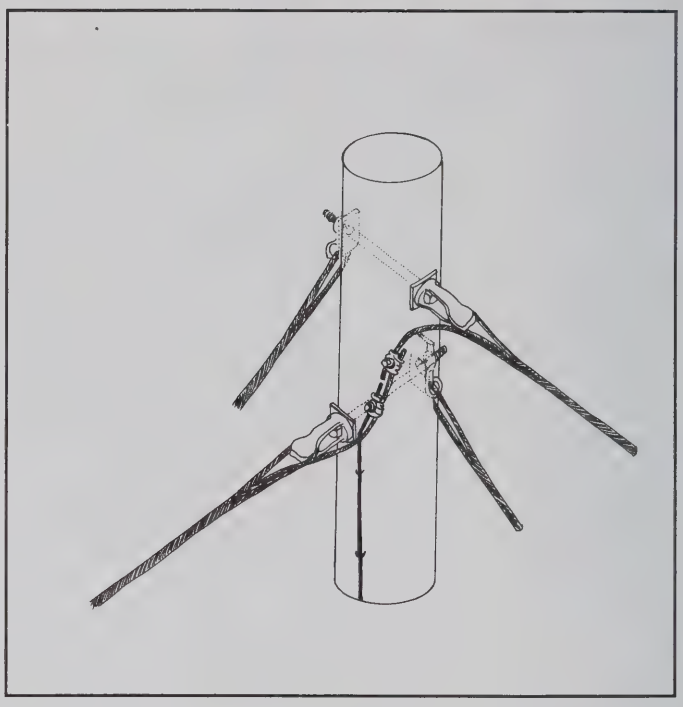


Figure 11.6: Double Dead-End Framing Hardware

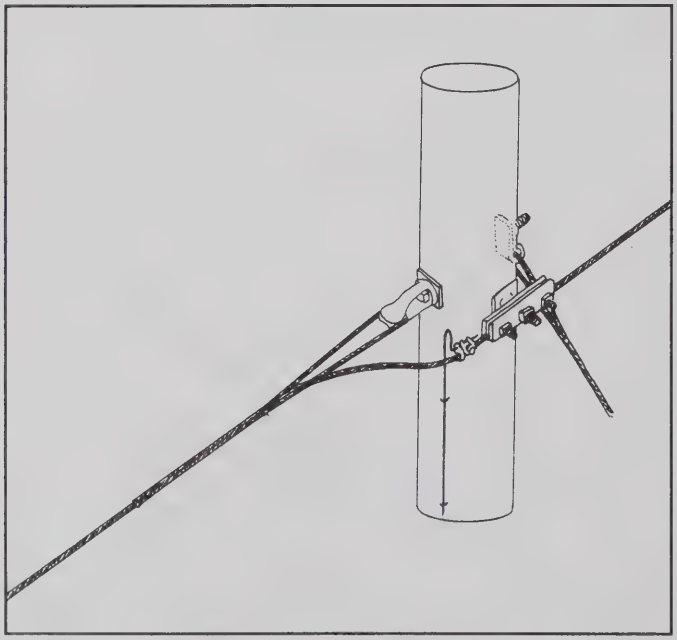


Figure 11.5: False Dead-End Framing Hardware

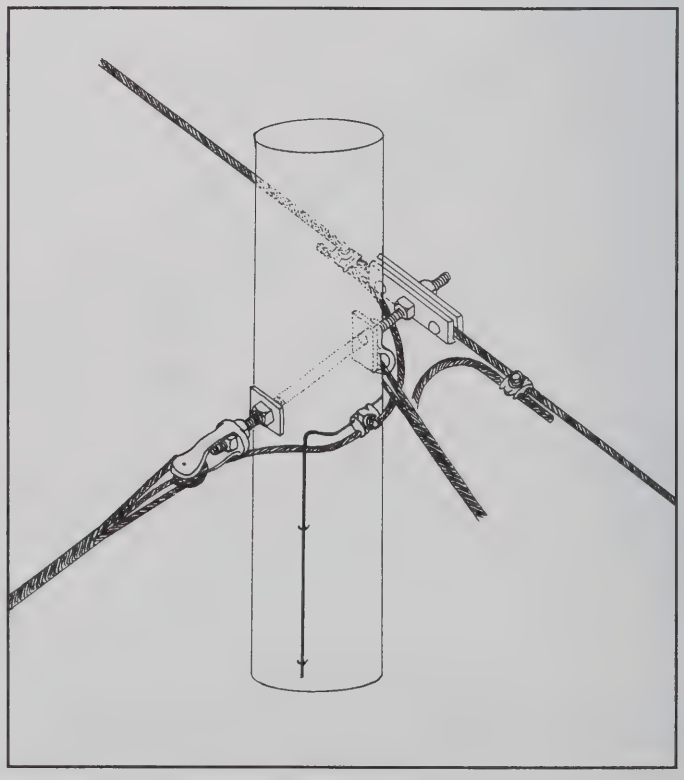


Figure 11.7: Line Pole Dead-End

3.0 Coaxial Cable Expansion Loop Configurations

Expansion and contraction of coaxial cable occurs due to temperature changes in the field. Expansion loops are used to prevent unrestrained movement of the cable at bends in the cable when expansion and contraction occurs. (See Section 9.) The proper placement of expansion loops for the hardware configurations as seen in the previous subsection is related as follows.

Figure 11.8: Expansion Loops, Straight Line Pole
Figure 11.9: Expansion Loops, Angled Pole
Figure 11.10: Expansion Loops, Mid-span Crossover
Figure 11.11: Expansion Loops, False Dead-End
Figure 11.12: Expansion Loops, Double Dead-End
Figure 11.13: Expansion Loops, Line Pole Dead-End

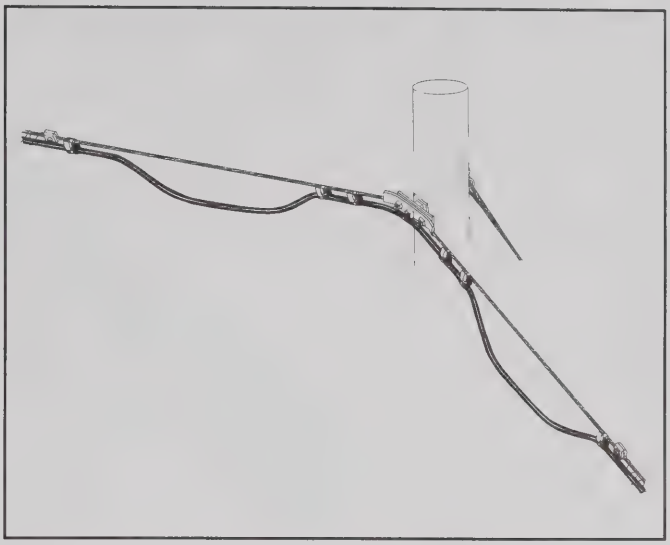


Figure 11.9: Expansion Loops, Angled Pole

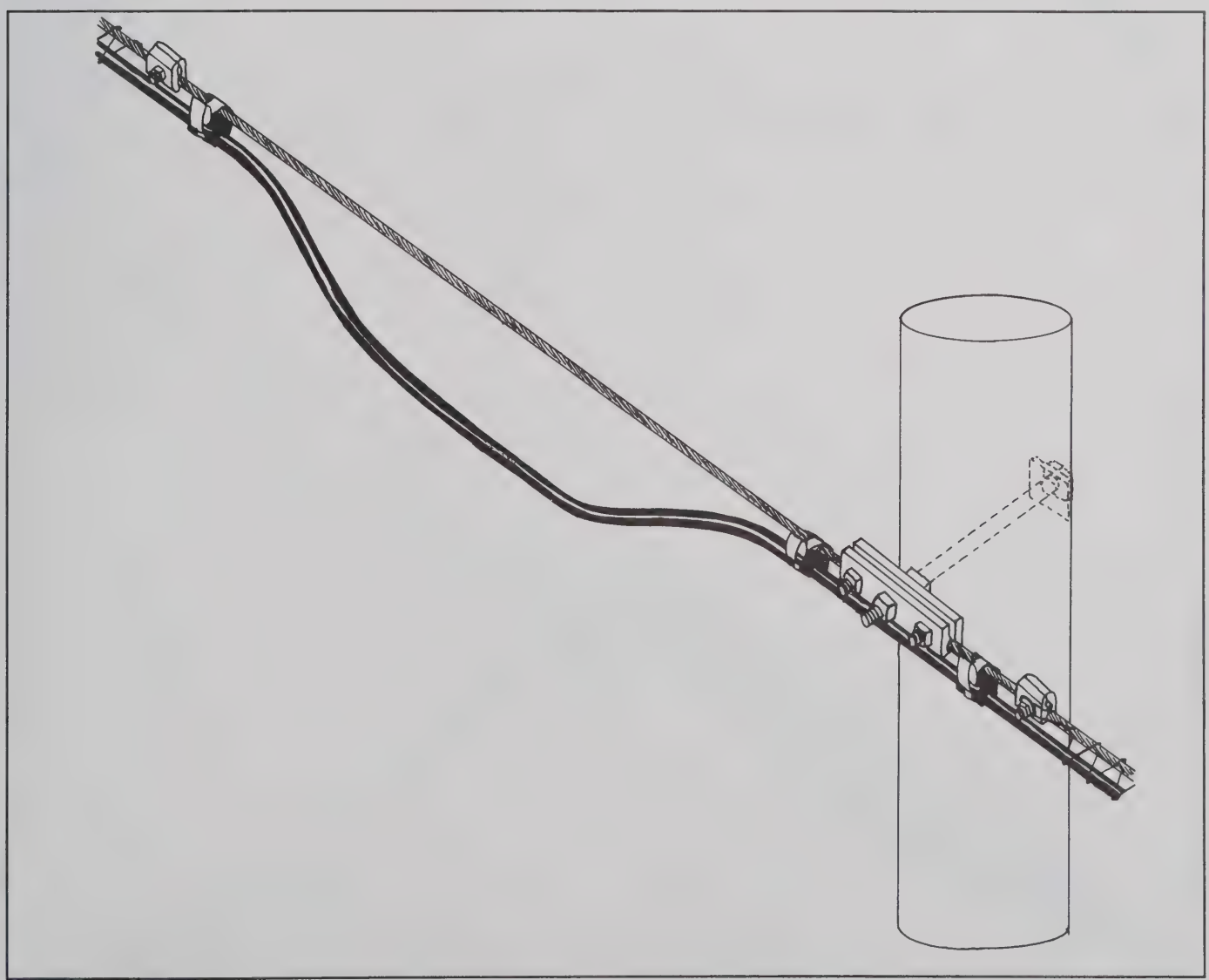


Figure 11.8: Expansion Loops, Straight Line Pole

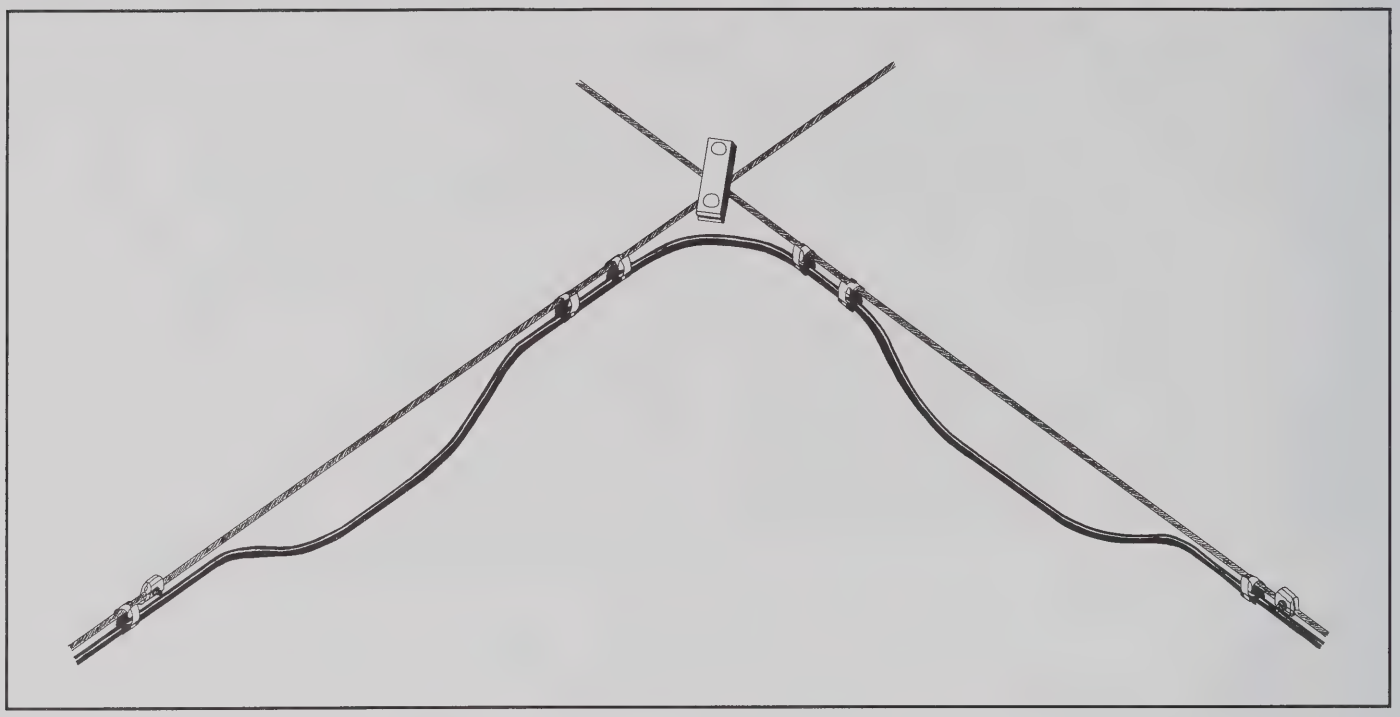


Figure 11.10: Expansion Loops, Mid-span Crossover

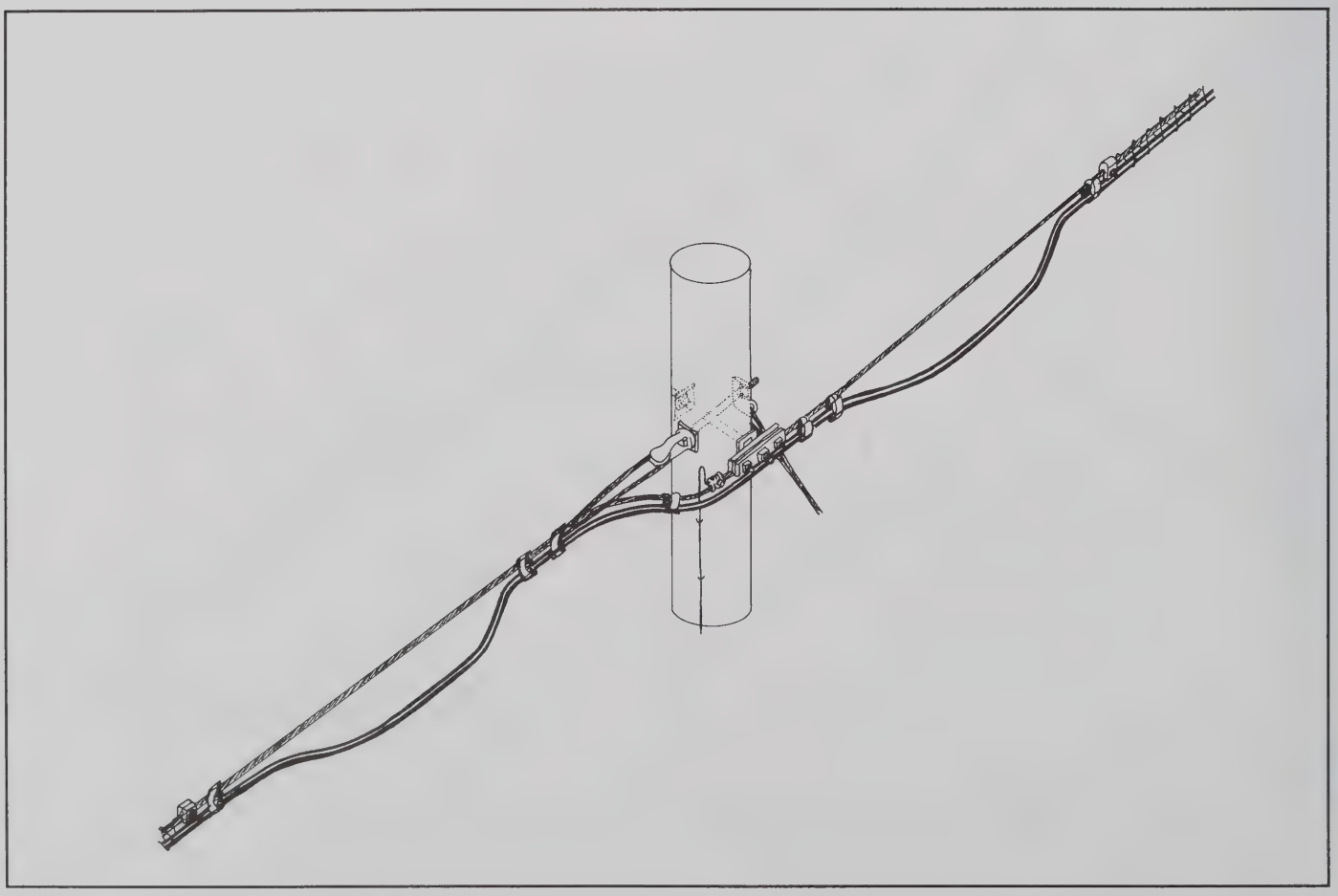


Figure 11.11: Expansion Loops, False Dead-End

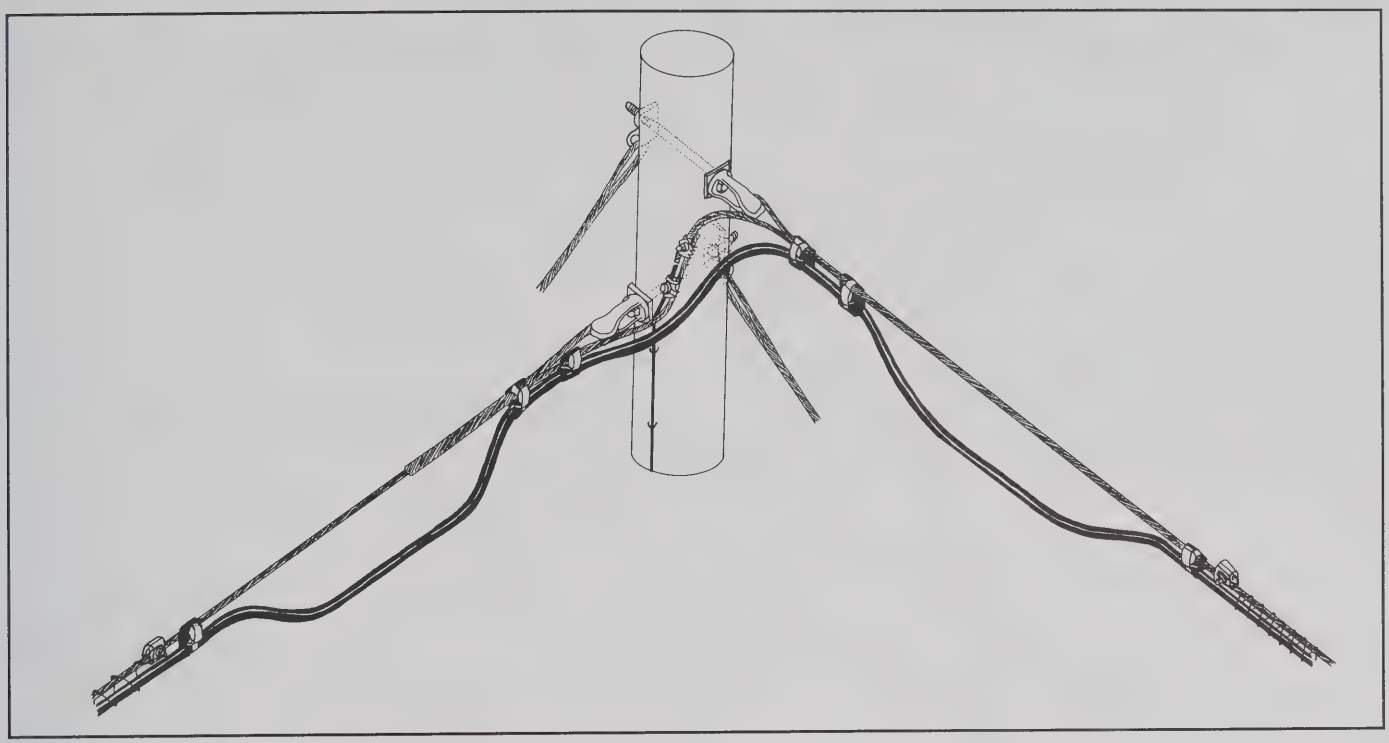


Figure 11.12: Expansion Loops, Double Dead-End

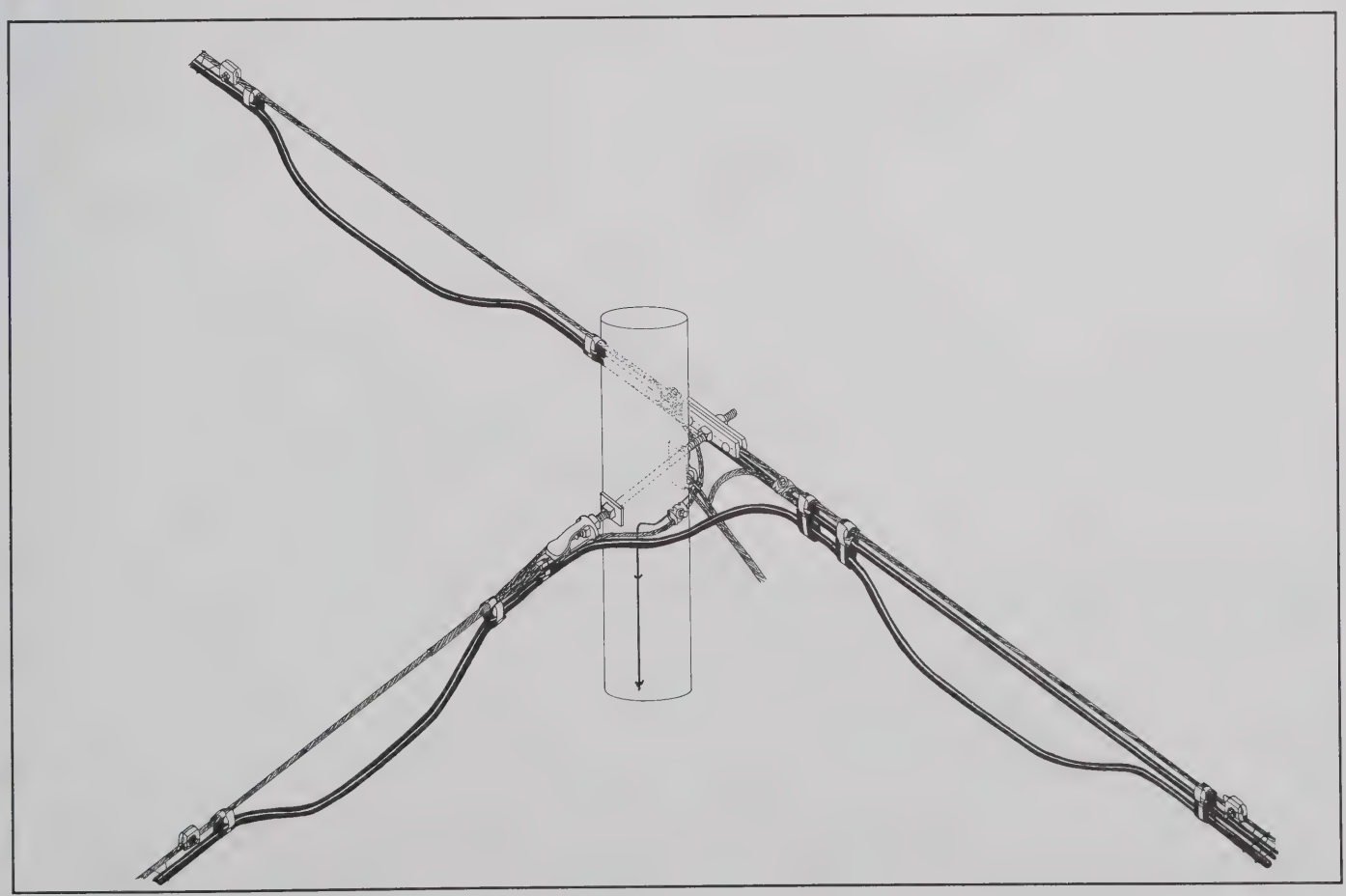


Figure 11.13: Expansion Loops, Line Pole Dead-End

4.0 Equipment Splicing Configurations

Many factors contribute to the complexity and variety of splicing configurations and techniques. This complexity and variety is due to the wide selection of: connectors, splicing tools, aerial support hardware configurations, subsurface enclosure configurations and cable types. The CommScope Construction Manual does not address splicing as a craft. The coaxial connector manufacturer in conjunction with the splicing tool manufacturer can specify appropriate coaxial cable practices for splicing. The fiber splice enclosure manufacturer in conjunction with the fiber splicing machine manufacturer can specify appropriate fiber optic practices for the particular splicing machine. Plant operator specifications normally dictate acceptable splice loss criteria.

Due to the complexity and variety of good configurations, fiber optic splice configurations as well as subsurface coaxial cable splice configurations will not be related in this section. General aerial splice configurations are reviewed as follows:

Figure 11.14: Splice Configuration, Tap

Figure 11.15: Splice Configuration, Directional Coupler

Figure 11.16: Splice Configuration, Line Extender

Figure 11.17: Splice Configuration, Line Extender and Directional Coupler

Figure 11.18: Splice Configuration, Main-Line Amplifier

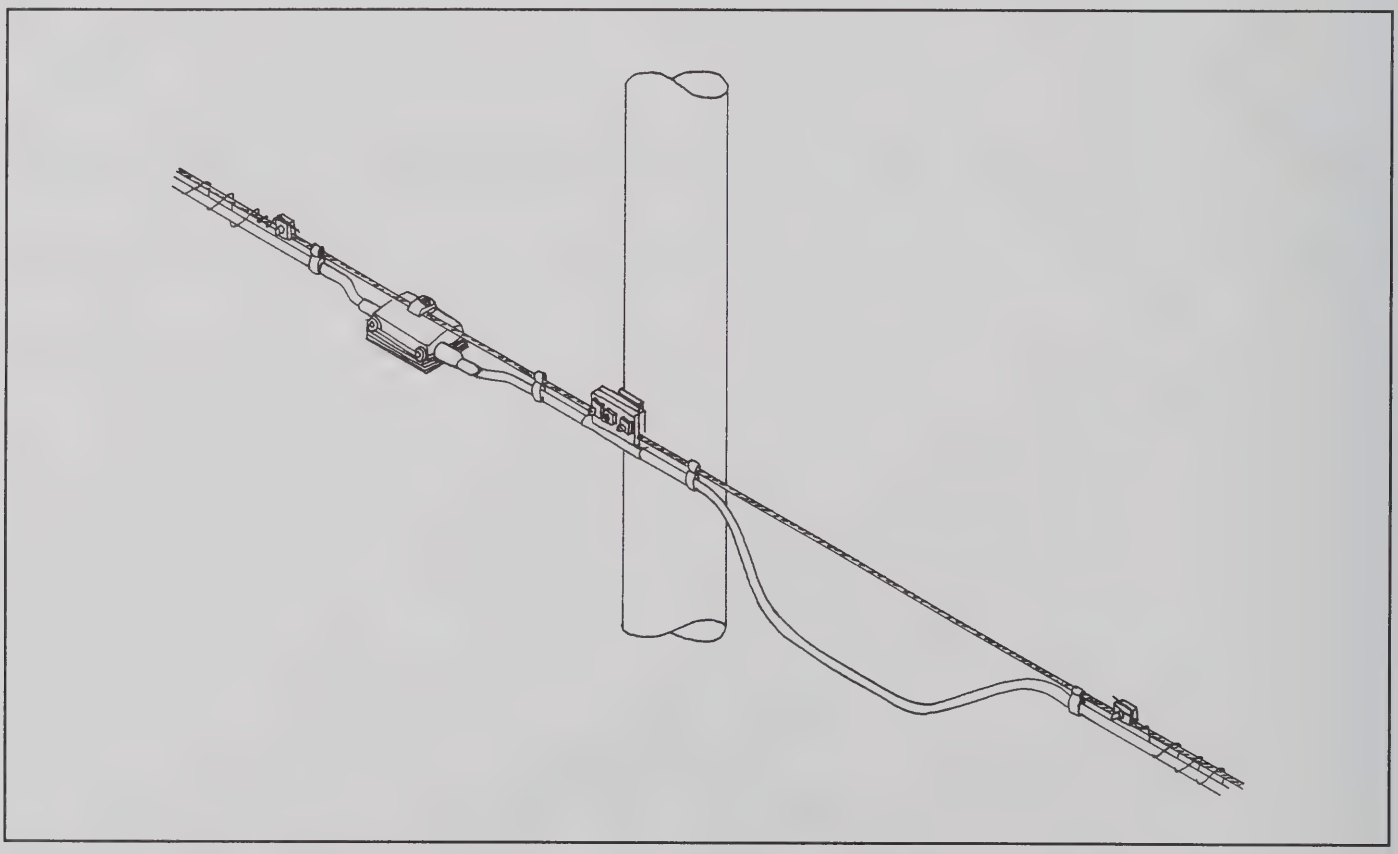


Figure 11.14: Splice Configuration, Tap

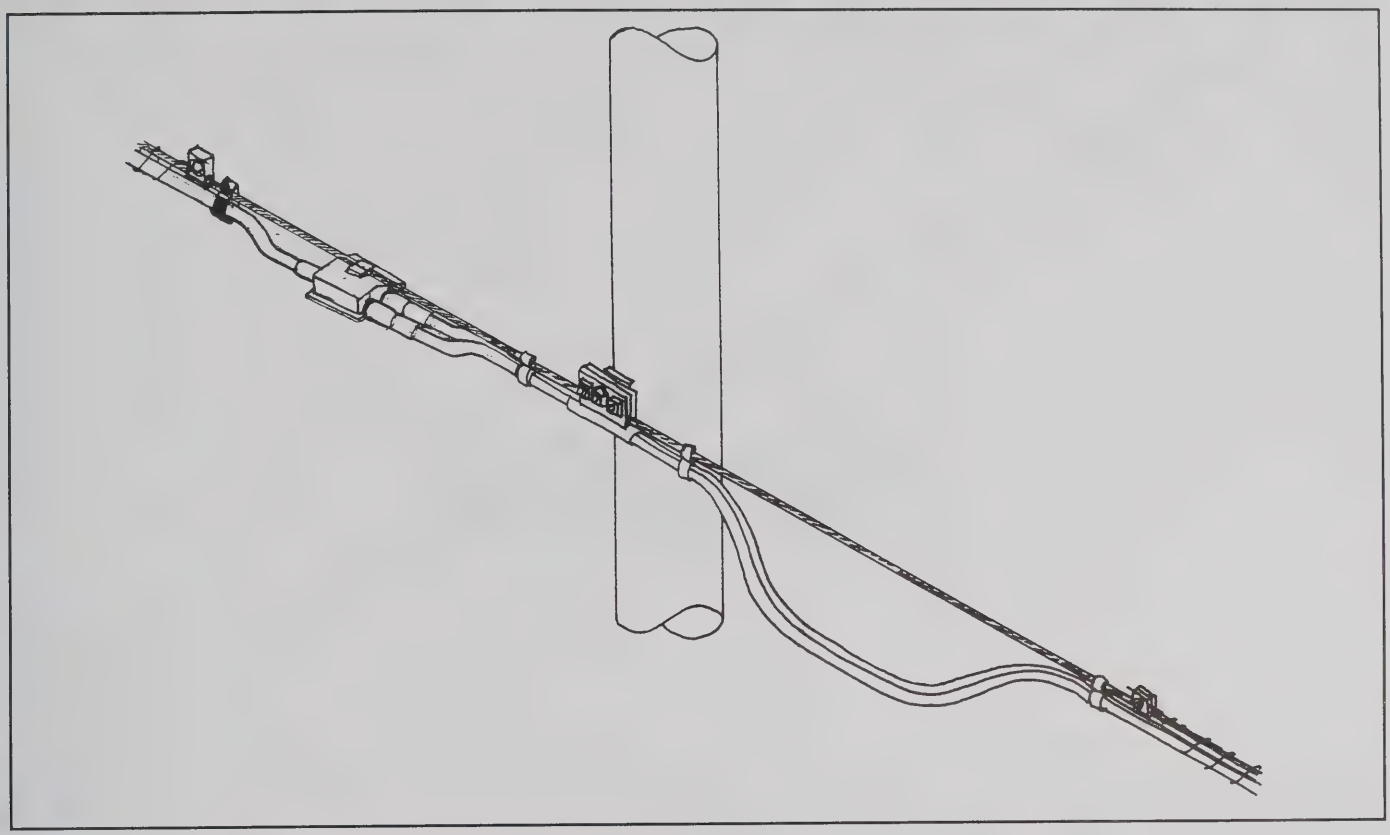


Figure 11.15: Splice Configuration, Directional Coupler

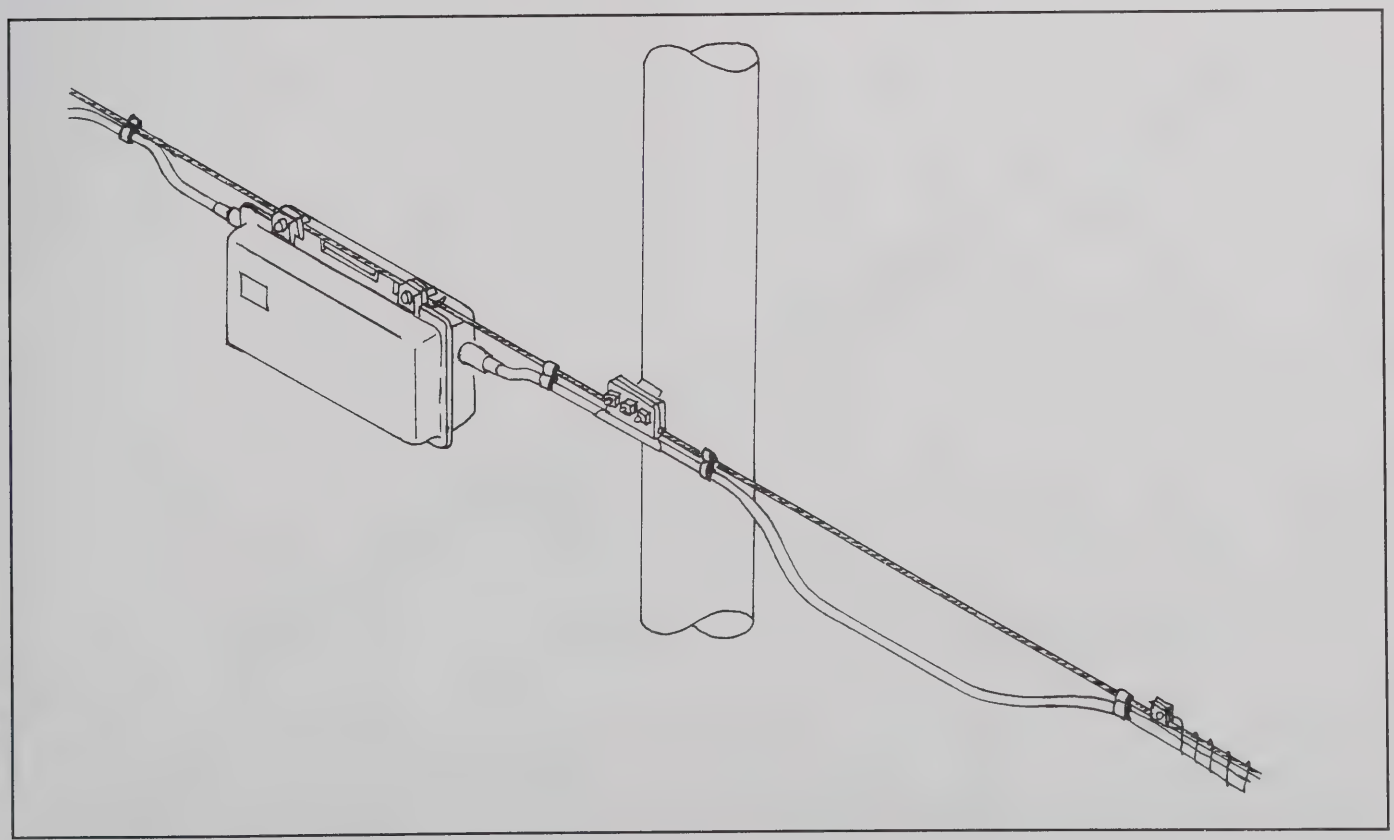


Figure 11.16: Splice Configuration, Line Extender

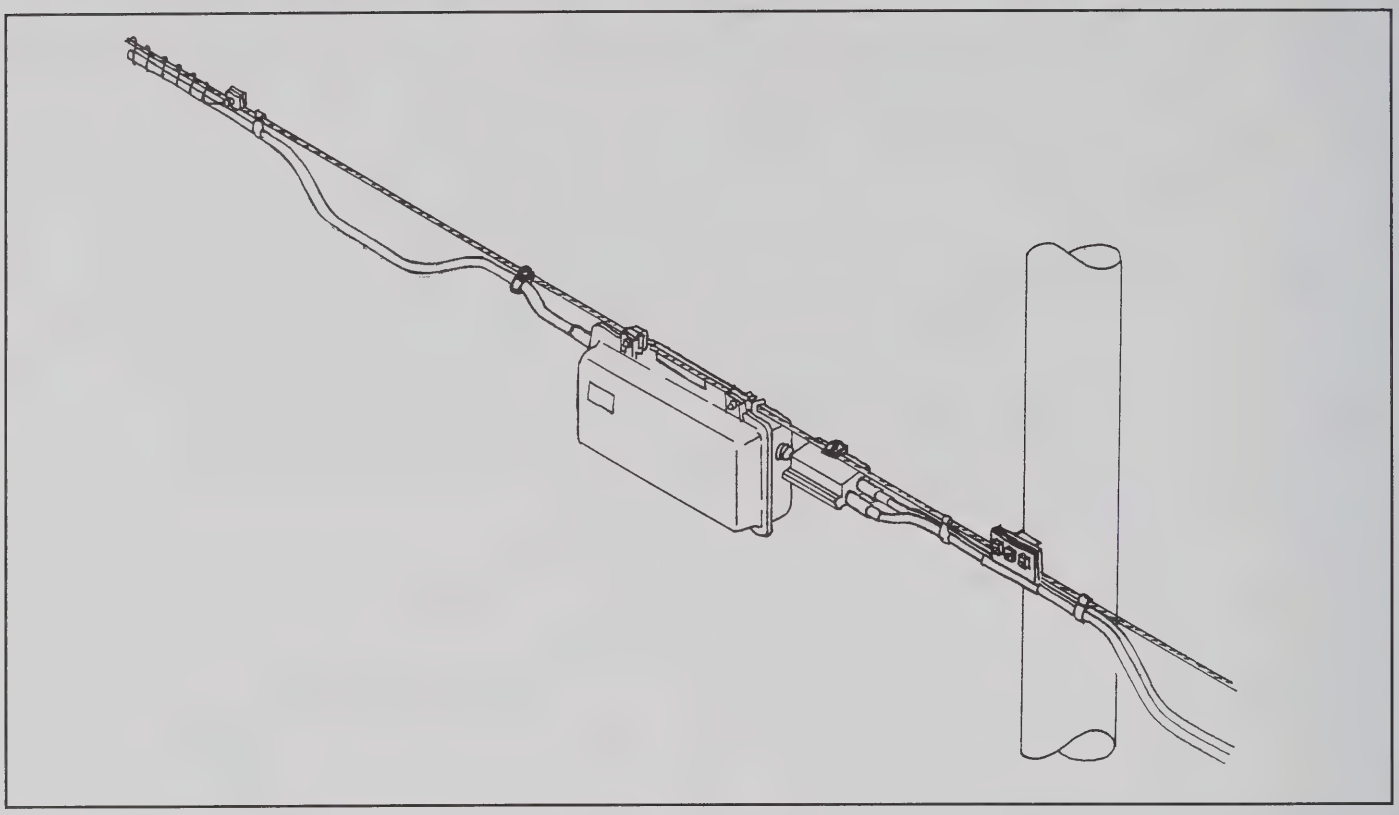


Figure 11.17: Splice Configuration, Line Extender and Directional Coupler

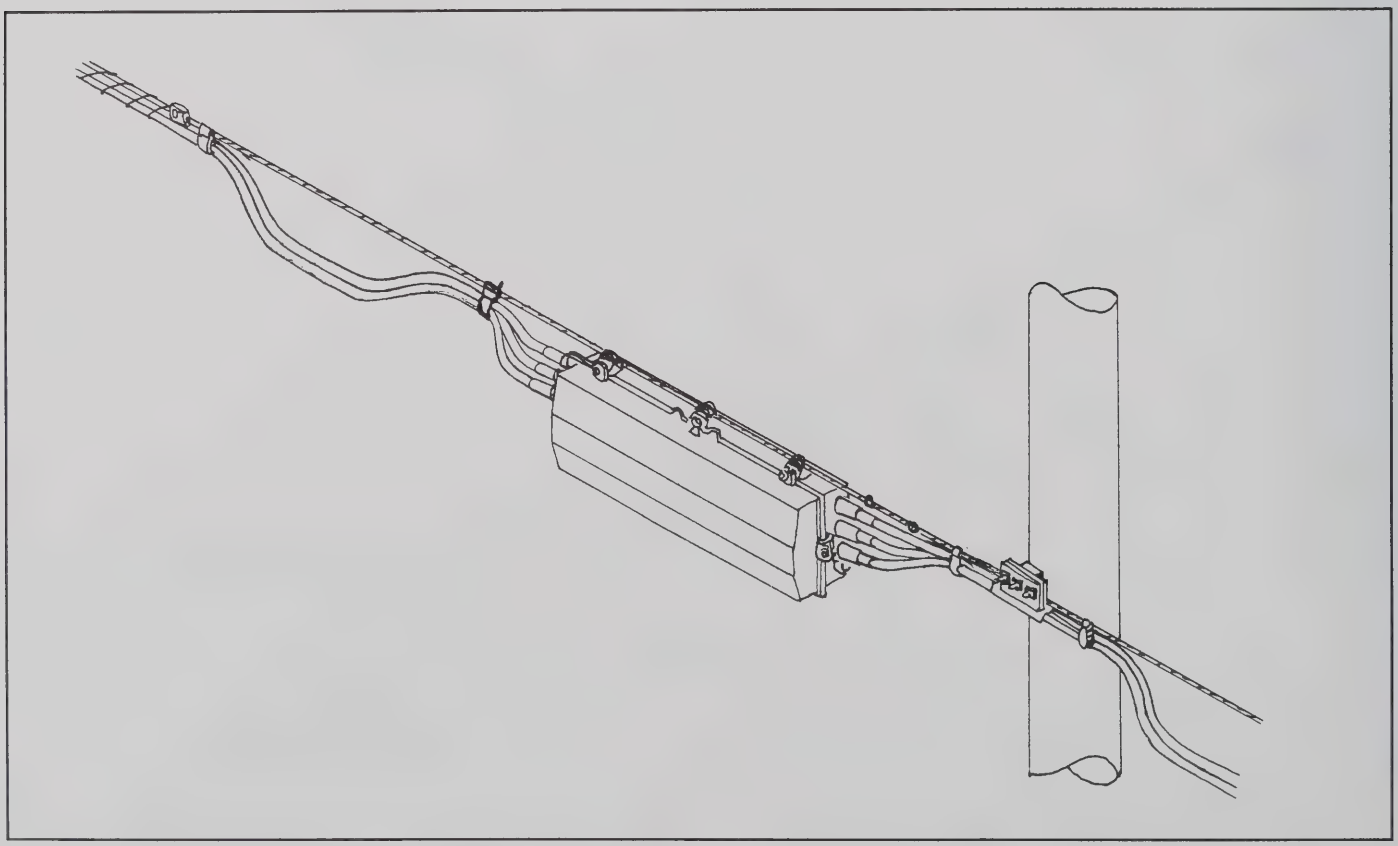


Figure 11.18: Splice Configuration, Main-Line Amplifier

Appendix

U.S. Department of Labor Regional Offices for the Occupational Safety and Health Administration.

Region I
(CT*, MA, ME, NH, RI, VT*)
133 Portland Street
First Floor
Boston, MA 02114
Telephone: (617) 565-7164

Region II
(NJ, NY*, PR*, VI*)
201 Varick Street
Room 670
New York, NY 10014
Telephone: (212) 337-2378

Region III
(DC, DE, MD*, PA, VA*, WV)
3535 Market Street
Philadelphia, PA 19104
Telephone: (215) 596-1201

Region IV
(AL, FL, GA, KY*, MS, NC*, SC*, TN*)
1375 Peachtree Street, NE
Suite 587
Atlanta, GA 30367
Telephone: (404) 347-3573

Region V
(IL, IN*, MI*, MN*, OH, WI)
230 South Dearborn Street
Room 3244
Chicago, IL 60604
Telephone: (312) 353-2220

Region VI
(AR, LA, NM*, OK, TX)
525 Griffin Street
Room 602
Dallas, TX 75202
Telephone: (214) 767-4731

Region VII
(IA*, KS, MO, NE)
911 Walnut Street, Room 406
Kansas City, MO 64106
Telephone: (816) 426-5861

Region VIII
(CO, MT, ND, SD, UT*, WY*)
Federal Building, Room 1576
1961 Stout Street
Denver, CO 80294
Telephone: (303) 844-3061

Region IX
(American Samoa, AZ*, CA*, Guam, HI*, NV*, Trust Territorise of the Pacific)
71 Stevenson Street
Room 415
San Francisco, CA 94105
Telephone: (415) 744-6670

Region X
(AK*, ID, OR*, WA*)
1111 Third Avenue
Suite 715
Seattle, WA 98101-3212
Telephone: (206) 442-5930

*These states and territories operate their own OSHA-approved job safety and health programs (Connecticut and New York plans cover public employees only.) States with approved programs must have a standard that is identical to, or at least as effective, as the federal standard.

Outline for OSHA Standards for Telecommunications

Section 1910.268 Telecommunications

a. Application

b. General

c. Training

d. Employee Protection in Public Work Areas

e. Tools and Personal Protective Equipment

f. Rubber Insulating Equipment

g. Personal Climbing Equipment

h. Ladders

i. Other Tools and Personal Protection Equipment

j. Vehicle-mounted Material Handling Devices and Other Mechanical Equipment

k. Materials Handling and Storage

l. Cable Fault Locating and Testing

m. Grounding for Employee Protection-Pole Lines

n. Overhead Lines

o. Underground Lines

p. Microwave Transmission

q. Tree Trimming-Electrical Hazards

r. Buried Facilities

s. Definitions

Vertical Clearances of Communications Cables from Supply Conductors and Equipment[1]

Supply Conductor or Equipment	Required Clearance
Conductor, > 8700 volts	40 inches plus 0.4 inches per kV above 8700 volts
Conductor, 0 - 8700 volts	40 inches
Transformer case, > 8700 volts non-grounded	40 inches plus 0.4 inches per kV above 8700 volts
Transformer case, > 8700 volts, effectively grounded	30 inches
Transformer case, 0 - 8700 volts non-grounded	40 inches
Transformer case, 0 - 8700 volts effectively grounded	30 inches
Capacitor case, > 8700 volts, non-grounded	40 inches plus 0.4 inches per kV above 8700 volts
Capacitor case, > 8700 volts, effectively grounded	30 inches
Capacitor case, 0 - 8700 volts, non-grounded	40 inches
Capacitor case, 0 - 8700 volts, non-grounded	30 inches
Street light bracket, non-grounded	20 inches
Street light bracket, effectively grounded	4 inches
Street light drip loop	12 inches

[1]Communications cables are located below the supply conductors and equipment.

Appendix D

SPANMASTER® RELEASE 2

Sag and Tension Worksheet

COMMSCOPE, INCORPORATED

6/92

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SPANMASTER®
RELEASE 2
Sag and Tension Worksheet

CommScope, Inc.

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DIFFERENCES BETWEEN RELEASE 2 AND EARLIER VERSIONS

Several enhancements have been made to **SPANMASTER®** based on input and suggestions by system operators and construction specialists. Separate output tables are now printed for NESC Rule 251 "Conductor Loading" and for Rule 232A "Vertical Clearances of Wires, Conductors, Cables, and Equipment Above Ground, Roadway, Rail or Water Surfaces." An output table is also generated to analyze the sag at any "point of interest" within a span. This allows the user to determine if the clearances are a problem anywhere within the span, not just at mid-span. In addition, an optional printout is available that shows the horizontal and vertical components of the sag. This feature is especially useful for examining vertical sag in areas with wind and little or no ice.

A major difference between **RELEASE 2** and earlier versions is the method used to calculate ice loadings. Work with consultants and the NCTA Engineering Committee has resulted in an interpretation of the NESC codes that are less severe for calculating ice loads than used in earlier **SPANMASTER®** versions. A detailed description of the ice loading calculation is given in APPENDIX I of this manual.

1.0 INTRODUCTION

SPANMASTER® RELEASE 2 is a program written to aid the construction specialist in defining the sag and tension characteristics of a span of cable. It can be used to determine the maximum span length for a given load and strand size or to examine a specified cable span under various loading conditions. The worksheet is particularly useful in examining compliance with NESC Rules 251 and 232A. This program was developed specifically for the CATV industry and will accept input of up to 4 cables lashed to a single messenger strand.

The program is a calculation tool. No assumptions are made regarding the application of the data generated. In other words, the tensions and sags are calculated based on the appropriate engineering equations, but the software does not attempt to make judgement decisions on the use of the information.

2.0 SYSTEM REQUIREMENTS

The program is compiled for use on IBM PC®, XT®, AT®, PS/2® and compatible computers. The system must have a minimum of 512K RAM and one floppy drive with a capacity of 1.2 MBytes or greater. Monitors supported include MDA, CGA, EGA, VGA and Hercules®.

Although the program runs on PC® (8086) and XT® (8088) class machines, the program is very calculation intensive and therefore runs with much greater speed and efficiency on AT®'s (286) or better.

3.0 HOW TO LOAD SPANMASTER® RELEASE 2

Make sure the files "SM2.EXE" and "SM2.WKB" are in your current directory. Type "SM2" and press <enter> to load the worksheet.

If you have only the minimum memory required, you may have to unload any resident or TSR (terminate stay ready) programs that may be in memory before running **SPANMASTER® RELEASE 2**. An "out of memory error" will warn you if this is necessary.

4.0 HOW TO USE SPANMASTER® RELEASE 2

The program operates in a similar manner to a spreadsheet, like LOTUS 123® or SYMPHONY®. The uppermost part of the work sheet (the top 23 lines) consists of the input section. Here, you can enter header information like NAME, DATE, SPAN ID, and NOTES. Also, there are tables for entering technical information on the messenger strand, span description and cables used in the span.

The lower portions of the worksheet are output tables where sag and tension results have been calculated based on the input information. Note that the output tables recalculate every time any input is changed. This is a valuable feature that allows the user to experiment with various input data. For example, with all other information held constant, the user could change the span length to various values and watch the changes occur in the output tables on the screen. At any time, the user can make a printout of the input and output tables.

The steps to using the program are as follows:

1) enter header information (name, date, notes, span ID),
2) enter strand data either manually or using AUTO ENTER,
3) enter cable data either manually or using AUTO ENTER,
4) enter span information manually,
5) view data tables and make changes in input if desired,
6) print tables using print function key.

4.1 Entering Strand Data

Strand data can be entered by two methods, using the AUTO ENTER function key or manually entering the data.

AUTO ENTER:
Information for several commonly used strand sizes is already contained in a **SPANMASTER® RELEASE 2** data table. This information can automatically be transferred into the "Strand Input" table by using the AUTO ENTER function.

To use AUTO ENTER, press <F3>. A pop-up menu appears. Move the cursor over the word "STRAND" and press enter. The pop-up menu then changes to a selection of strand sizes. Select the one you want by moving the cursor over it and pressing <enter>. All the appropriate data is then automatically entered into the correct areas on the screen (called cells). To view the data table, press <F6> and select "STRAND_DATA". All the available strand data will be displayed on the screen in a pop-up menu. It is possible to print the strand data table using the steps discussed in Section 4.4.

MANUAL DATA ENTRY:
If you are not using a popular strand type, and the data is not available in the AUTO ENTER function, the information must be entered manually. The data required are the cross sectional area, elastic modulus, diameter, thermal expansion coefficient, and weight per unit length of your strand. This information is available from the strand manufacturer. Please take precautions to ensure that the data entered uses the same units as those indicated in the worksheet.

To manually enter data, simply move the cursor using the cursor control keys to the cell where you wish to input data. Then type in the information and press <enter>. If you press the escape key <esc> before you press <enter>, the information will not be placed in the cell.

You can also enter data by moving the cursor to the desired cell and pressing function key 2 <F2>. This allows you to edit the contents in the cell, rather than simply replacing it. Press <enter> when you are finished editing.

Pressing <F2> twice will place the cell contents into a pop-up window for easier editing. Again, press <enter> to place the edited information into the cell or press <esc> to "escape" from the edit mode without changing the cell contents.
Note that the program will not allow you to enter information into any cell that contains permanent information. If you try, you get a beep and a "protected cell" message. Try it, no damage is done. You must press the escape key <esc> to remove the "protected cell" message.

4.2 Entering Cable Data

Cable data can also be entered using the AUTO ENTER function or by entering manually.

The AUTO ENTER function is again accessed by pressing <F3>. Select the cable position number and continue through the menu selections until the cable has been specified. Cable position number is described more fully in Section 5.

Data for all the major CommScope trunk and distribution cables are contained in the AUTO ENTER data tables. Entering data manually is the same procedure as described in Section 4.1. The same information is required, i.e., cross-sectional area, effective elastic modulus, diameter, effective thermal expansion coefficient and cable weight per unit length.

NOTE: Effective elastic modulus and effective thermal expansion coefficient for cables are only required for calculations of Figure 8 (integrated messenger) constructions. See Section 4.2 for more details on Figure 8 constructions.

4.3 Entering Span Information

The remaining input table is for span data input. Data in this section must be entered manually as described in Section 4.1. This is where span length, desired sag and installation temperature are entered. Please note the units shown in the worksheet. The data generated by the program will assume a service temperature range of -40 °F to 140 °F.

An optional input cell is labeled "Clearance". In some instances, it is convenient to characterize a span by the ground clearance at mid span. The temperature table then shows the calculated clearance at each temperature. (See Appendix V - Definitions) If zero ("0.00") is entered into the clearance cell, then the temperature table simply shows "Not Applicable" in the clearance column.

4.4 Printing Tables

Pressing the F4 key will bring up a pop-up menu showing print options. The first choice to make is to send output to a printer or to a disk file. The printer options are as follows:

- Print input information and output tables for the current span.
- Print physical data for CommScope cables.
- Print physical data for popular strand sizes.
- Print sag vector analysis table for the current span.
- Print sag and tension data at a "point of interest" within the current span.

Simply select the desired option and the information is sent to your printer (Extended ASCII format).

If you wish to send output to a disk file, the following options are available:

- Print input information and output tables for the current span.
- Print sag vector analysis table for the current span.
- Print sag and tension data at a "point of interest" within the current span.

In addition, program features are available to allow custom printing to either printers or disk files. See Section 4.5 for more details.

4.5 Other Program Features

Several other features in the program can be accessed by pressing <F5>, the menu key. A list of options will appear at the top of the screen with selections similar to that used in many commercially available spreadsheets. These options include:

Video display options,

- change colors,
- change display type,
- load and save display settings,
- change character size.

File saving and retrieving,

This is a valuable feature that allows the user to save the entire contents of a span analysis. All the input and output information is saved in a disk file and can be retrieved back into **SPANMASTER® RELEASE 2** later.

Print files to disk,

As mentioned in Section 4.4 above, several options are available for printing files to disk using the <F4> key. In addition, more printer options are available through the menu functions. Press <F5>, move the cursor to "print" and press enter. The print features are similar to those of many commercial spreadsheets.

Erase ranges of input data,

This feature can be used to erase ranges of input information. Only information in "unprotected" cells can be erased. If an attempt is made to erase permanent information, a "Protected Cell" error message appears. Press <esc> to remove the message and continue usage of the software.

It is also possible to display tables of information on the screen for temporary inspection. To access this feature, press <F6>. A menu appears allowing the selection of the type of data you wish to review. Simply move the cursor over the item desired and press <enter>. Physical data on cables and strands and a summary table on NESC loading rules are available for instant display using this feature.

5.0 APPLICATION TIPS

5.1 Multiple Cables on the Same Strand

Because overlash situations are so common in the CATV industry, **SPANMASTER® RELEASE 2** allows for up to four cables to be carried by the same messenger. Data can be entered (either manually or using AUTO ENTER) in each of the four cable positions. It is possible to analyze spans with more than four cables, but a few manual calculations are required. See APPENDIX III.

NOTE: There is nothing special about any of the cable positions. Data entered in position 4 has the same effect as data entered in position 1, 2 or 3. The one exception to this rule is that position 1 is the only position that can be set to a Figure 8 cable.

5.2 Figure 8 Cables

Cable position 1 allows the option for a Figure 8 or integrated messenger cable. When a "y" or "Y" is entered into the column under "Figure 8 Cable?", the messenger described in "Strand Input" is assumed to be in an integrated configuration with the cable described in cable position 1. When any other letter or character is entered under the "Figure 8 Cable?" column, the worksheet assumes the cables are not integrated.

Figure 8 configurations behave differently than dedicated messengers with cables lashed to them. The difference is that the cable that is integrated to the messenger contributes to the load bearing capacity of the cable assembly. On the other hand, when dedicated messengers are used, **SPANMASTER® RELEASE 2** assumes that the messenger carries all the load.

Try it.

- Select a strand size and enter the data using AUTO ENTER.
- Select a cable for cable position 1 using AUTO ENTER.
- Enter span length, installation temperature and sag.
- Move the cursor down so that the "Span Output Data" is visible.
- Now, move the cursor to the field under "Figure 8 Cable?", press "y" and press the "enter" key.
- Alternate entering "y" and "n" and watch the output data change. Remember, all the output data tables are affected by making cable position 1 into a Figure 8 cable.

Although overlashing a Figure 8 cable is not very common, **SPANMASTER® RELEASE 2** will allow calculations of multiple cables added to the integrated cable. Simply input cable data in cable positions 2, 3 or 4.

5.3 Fiber Optic Cables

Fiber optic cables are handled essentially the same as coaxial cables for sag and tension calculations with one important exception. Cable strain must be considered for fiber optic cables.

Most fiber optic cables used in outside plant have a "tensile window" where the cable can stretch without the fibers experiencing undue strain. If the cable is stretched beyond the window, then the fibers begin to experience strain levels sufficient to increase the risk of breakage. Typical tensile windows range from 0.25% to 0.5% strain. Contact your cable supplier for information about your particular cables.

Several columns of data in **SPANMASTER® RELEASE 2** are labeled "% LENGTH CHANGE FROM SPAN INPUT CONDITIONS." These columns show the amount of strand elongation since initial installation. It is reasonable to expect that cables lashed to the strand will experience the same elongation in at least part of the span. In fact, since **SPANMASTER® RELEASE 2** considers the strand as the only load bearing component (except with Figure 8 cables), these elongation values are worst case.

If the values in the columns, "% LENGTH CHANGE FROM SPAN INPUT CONDITIONS", are greater than the tensile window for your cable, judgement must be made on the wisdom of the installation conditions. Small excursions of cable elongation beyond the cable tensile window, under worst case conditions, are not always considered to be a problem. Few cable manufacturers, however, will recommend exceeding the tensile window at any time.

The risk of over-elongating the cable is that fibers will break prematurely. Typically, fibers under tensile load will not show an attenuation increase. Fibers that have been over-stressed and did not break are impossible to distinguish from unstressed fibers in the field.

5.4 Strand Creep

Steel messengers, both stranded and solid, exhibit some permanent elongation (called

creep) when subjected to loads. The amount of creep depends on the load history of the messenger and varies with strand manufacturer. Steel messengers subjected to high loads for long periods of time will creep more than an identical messenger subjected to lower loads and shorter durations. **SPANMASTER® RELEASE 2** incorporates creep into the calculations for the output table for Rule 232A. No assumptions are made in the program about the amount of creep the messenger exhibits, which must be manually entered under the cell labeled "CREEP (in/in)." Tables for creep are available from some strand manufacturers. Values will typically range from 0.0001 to 0.0015 in/in, depending on the messenger size and load history. For stranded messenger, values from 0.0007 to 0.0010 in/in are commonly encountered.

Keep in mind that the creep value in the strand input section does not change automatically. It must always be changed manually, even when you use AUTO ENTER to change the strand input information.

5.5 Ice and Wind Loading

Ice and wind loading calculations are made according to NESC guidelines, Rule 250, "General Loading Requirements and Maps," 1990 Edition. The NESC divides the United States into three loading districts: heavy, medium and light. Table 1 shows a summary for the loading considerations for each of the districts.
Rule 251, "Conductor Loading" gives details on how to apply the requirements of Rule 250 to aerial plant.

An additional consideration is compliance with NESC Rule 232A, "Vertical Clearances of Wires, Conductors, Cables, and Equipment Above Ground, Roadway, Rail or Water Surfaces." In this rule, clearances are specified under loading conditions that are different from Rule 251. Rules 232A-1 and 232A-2 require that sag be examined at 120 °F (or maximum service temperature if higher than 120 °F) with no wind. In addition, 232A-3 requires that sag be determined under the ice loading for the district, but using 32 °F instead of the temperatures given in Rule 251. Table 2 summarizes the loading conditions for Rule 232A-3. **SPANMASTER® RELEASE 2** can

provide all of the calculations necessary to examine compliance with these rules. It is necessary that the user take care to ensure that the desired temperatures and wind loadings are entered into the cells of the output data tables according to the NESC rule desired (either Rule 251 or Rule 232A). The temperature and wind loadings can be changed to values other than those specified by the NESC. If this is done, **SPANMASTER® RELEASE 2** changes the headings of the output tables to "Special" instead of the normal NESC labels.

	Heavy	Medium	Light
Radial thickness of ice (in)	**0.50**	**0.25**	**0**
Horizontal wind pressure (lbs per sq. ft.)	**4**	**4**	**9**
Temperature (°F)	**0**	**+15**	**+30**

Source: National Electrical Safety Code, 1990 Edition, p. 279, published by The Institute of Electrical and Electronics Engineers, Inc.

Table 1 - General loading requirements for NESC loading districts. Taken from Rule 250, Table 250-1.

	Heavy	Medium	Light
Radial thickness of ice (in)	**0.50**	**0.25**	**0**
Horizontal wind pressure (lbs per sq. ft.)	**0**	**0**	**0**
Temperature (°F)	**+32**	**+32**	**+32**

Source: National Electrical Safety Code, 1990 Edition, p. 156, published by The Institute of Electrical and Electronics Engineers, Inc.

Table 2 - Loading Requirements for NESC Rule 232A-3, which applies to vertical clearances of above ground wires.

Figure 1 illustrates how the resultant load is calculated for each district and is based on NESC Rule 251 "Conductor Loading," 1990 Edition. Note that wind loading is

considered to be horizontal to the cable and, therefore, the resultant load is not vertical in direction.

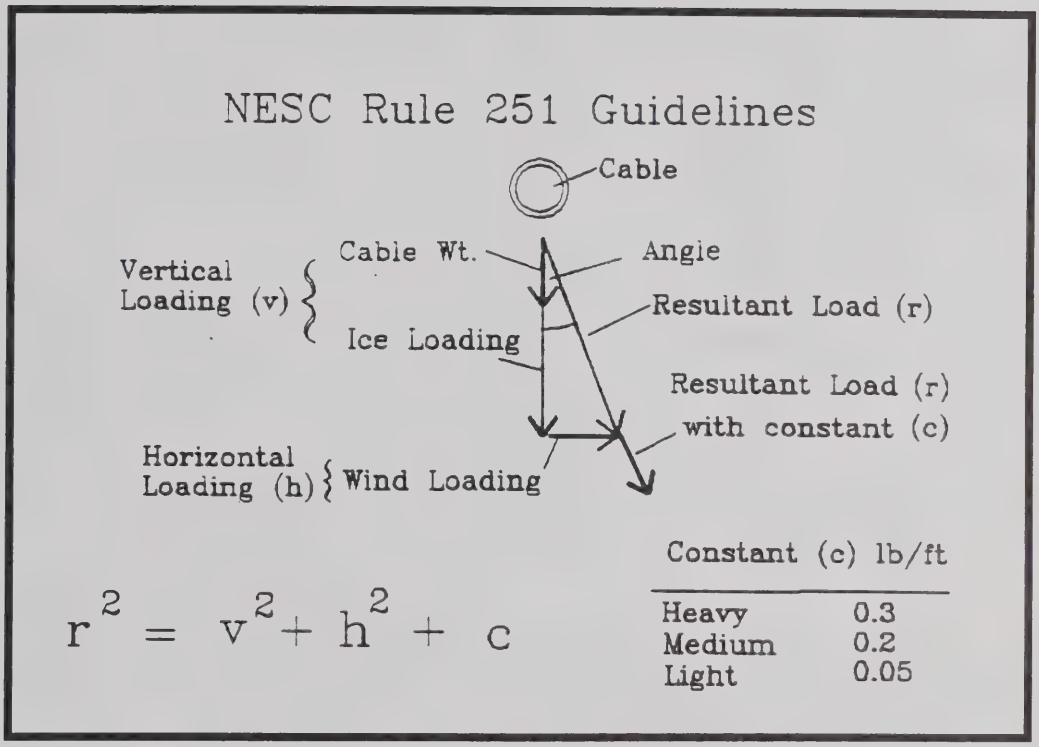

Figure 1 - Resultant load for cables is calculated based on the vertical and horizontal components. NESC Rule 251 requires that a constant be added to the resultant to get the total loading condition.

APPENDIX I - ICE LOADING CALCULATIONS

The method used to calculate ice loading on multiple cables lashed to a single messenger can significantly affect the calculated loading for the span. Unlike previous versions of **SPANMASTER®**, RELEASE 2 uses the "hollow cylinder" approach that is described in NESC Rule 251 A3. A hollow cylinder of ice around a cable bundle is obviously not a reflection of ice formation in the field. However, inputs from CATV and utility industry consultants have pointed out that this is the method required by the NESC to calculate ice loadings.

SPANMASTER® RELEASE 2 looks for the number of cables in order to determine how to calculate the diameter of the hollow cylinder of ice. **SPANMASTER** considers a cable to be present if values are present in the "DIA." and "WEIGHT" cells in the cable input section (i.e., cable position 1, 2, 3 or 4).
Below are the calculations used for each case.

Case 1 - One cable lashed to a messenger.

For this case, a hollow cylinder of ice is calculated where the inner diameter of the cylinder is simply the sum of the cable and strand diameters. An ice layer of 1/2" (heavy loading) or 1/4" (medium loading) is added to this circle diameter to form the ice cylinder. Figure 2 is an illustration of this case.

$$Dia_{cyl}=Dia_{strand}+Dia_{cable} \quad (1)$$

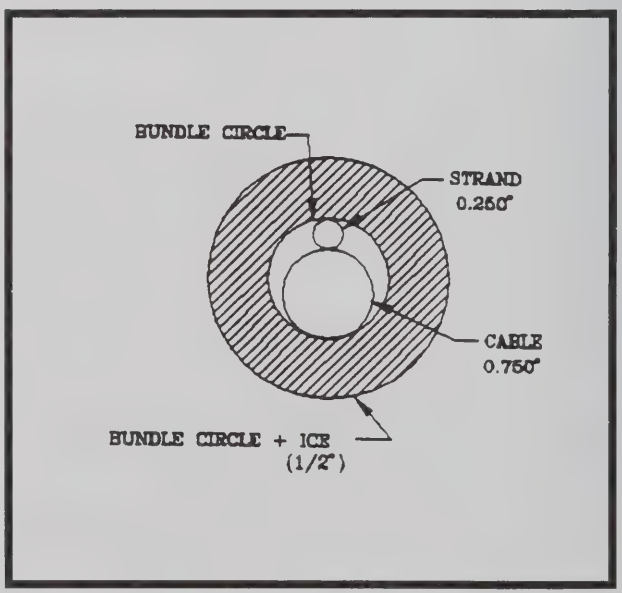

Figure 2 - Case 1, example of one cable lashed to a strand with ice.

Case 2 - Two cables lashed to a messenger.

For this case, the inner diameter of the hollow cylinder is the sum of the diameters of the two cables. Figure 3 illustrates.

$$Dia_{cyl}=Dia_{cable1}+Dia_{cable2} \quad (2)$$

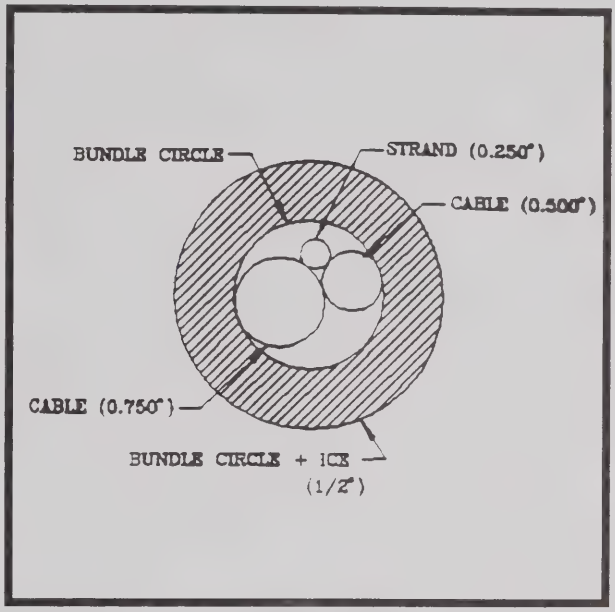

Figure 3 - Case 2, example of two cables lashed to a strand with ice.

Case 3 - Three or four cables lashed to a messenger.

Determining the cylinder diameter for three or more cables is considerably more complex. The possible configurations to consider number in the millions. **SPANMASTER® RELEASE 2** analyzes the geometry of the cable bundle and calculates the diameter of the bundle assuming closely packed cables. **It is important for the user to understand the approach used to determine the bundle diameter.** If, for any reason, the user does not believe that this method accurately estimates the bundle diameter of the cables in question, then the method described in APPENDIX III can be used to manually input cable bundle information.

Figure 4 on page 20 illustrates an example cable configuration with four cables. The following discussion refers to the parameters shown in Figure 4.

The center point of each cable must be determined on a x-y coordinate system. The origin of the x-y coordinate system is fixed at the center of cable 1, thus the coordinates of the center of the first cable are (0,0). The second cable is fixed with its center on the x axis, making its coordinates $(r_1+r_2,0)$.

In order to find (x_3,y_3), it is necessary to find Θ_1 using the law of cosines:

$$c^2=a^2+b^2-2ab\cos(\Theta_1) \quad (3)$$

where the values of a, b and c are indicated in Figure 4. Θ_1 is found by rearranging equation (3) and substituting cable radii as follows:

$$\Theta_1=Acos^{-1}\left[\frac{(r_1+r_2)^2+(r_1+r_3)^2-(r_2+r_3)^2}{2\times(r_1+r_2)(r_1+r_3)}\right] \quad (4)$$

x_3 and y_3 are solved for as follows:

$$x_3=\cos(-\Theta_1)\times(r_1+r_3) \quad (5)$$

$$y_3=\sin(-\Theta_1)\times(r_1+r_3) \quad (6)$$

Similarly, Θ_2, x_4 and y_4 can be found,

$$\Theta_2=Acos^{-1}\left[\frac{(r_1+r_3)^2+(r_1+r_4)^2-(r_3+r_4)^2}{2\times(r_1+r_3)(r_1+r_4)}\right] \quad (7)$$

$$x_4=\cos(-\Theta_1-\Theta_2)\times(r_1+r_4) \quad (8)$$

$$y_4=\cos(-\Theta_1-\Theta_2)\times(r_1+r_4) \quad (9)$$

Now that each cable has been located on the coordinate system, it is necessary to fit a circle over the entire bundle. First, an estimate is made of the center of the bundle circle. This is achieved by finding the smallest and largest x and y values defined by any circle and then finding the midpoint between those values.

Start with x:

x_{min} = smallest of,

$$\begin{matrix} x_1 - r_1 \\ x_2 - r_2 \\ x_3 - r_3 \\ x_4 - r_4 \end{matrix} \qquad (10)$$

x_{max} = largest of,

$$\begin{matrix} x_1 + r_1 \\ x_2 + r_2 \\ x_3 + r_3 \\ x_4 + r_4 \end{matrix} \qquad (11)$$

An estimate of the x-coordinate (x_c) of the bundle circle center is given by:

$$x_c = x_{min} + \frac{(x_{max} - x_{min})}{2} \qquad (12)$$

Using the same steps, y_c can also be estimated.

The radius of the bundle circle can be estimated by,

r_{bundle} = largest of,

$$\begin{matrix} r_1 + [\,(x_1 - x_c)^2 + (y_1 - y_c)^2\,]^{1/2} \\ r_2 + [\,(x_2 - x_c)^2 + (y_2 - y_c)^2\,]^{1/2} \\ r_3 + [\,(x_3 - x_c)^2 + (y_3 - y_c)^2\,]^{1/2} \\ r_4 + [\,(x_4 - x_c)^2 + (y_4 - y_c)^2\,]^{1/2} \end{matrix} \qquad (13)$$

The estimate for the bundle circle radius is then refined by incrementing and decrementing the values of x_c and y_c and recalculating the bundle radius in equation (13). Thus, the minimum bundle circle radius is determined.

Also, it should be noted that cable sizes are sorted by diameter when constructing the x-y coordinate system, regardless of the order the cables are entered in the input section. The largest cable is always cable 1, the next largest cable 2, etc. This provides "close packing" of the cables. For large cable bundles, the strand is assumed to be "nested" between the cables and does not contribute to the overall bundle diameter.

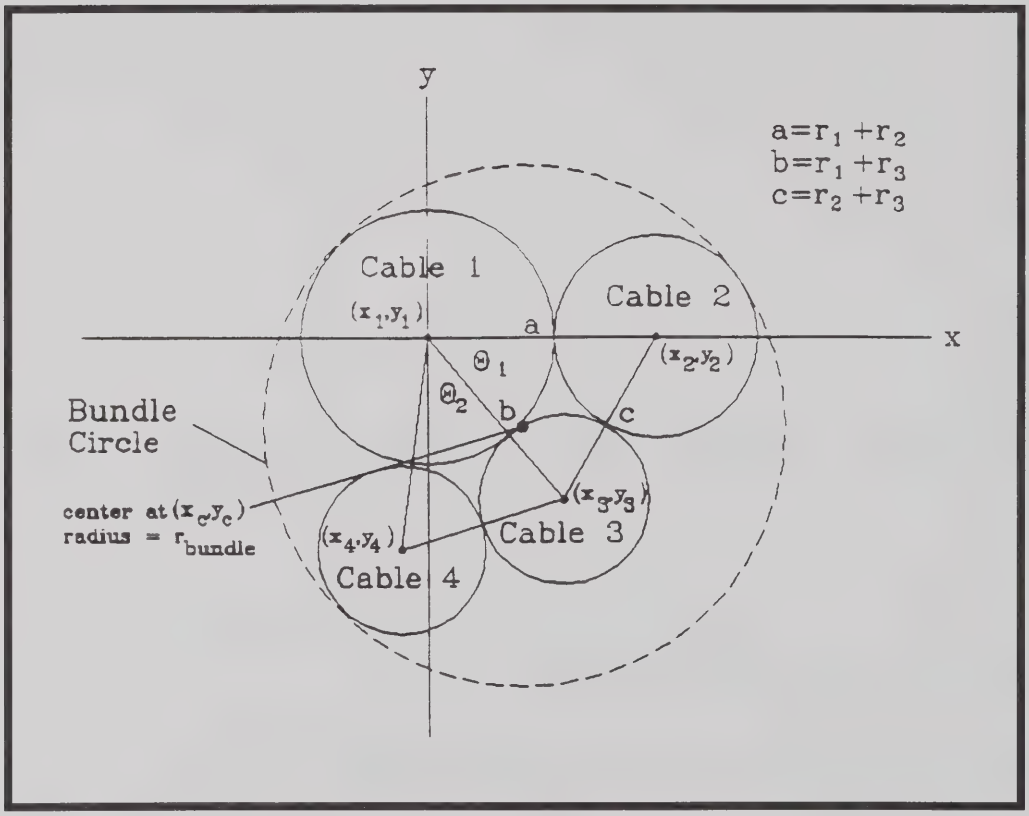

Figure 4 - Case 3, three or four cables. Diagram shows geometry of typical 4 cable bundle.

APPENDIX II - WIND LOADING CALCULATIONS

Wind loading is calculated based on the pressure exerted by the wind and the area profile the cable bundle presents to the wind. Wind pressures are defined for each loading district and are expressed in units of pounds per square foot (psf). Tables 1 and 2 in Section 5.5 of this manual give wind pressures for NESC Rules 251 and 232A.

SPANMASTER® RELEASE 2 calculates the bundle profile area by multiplying the bundle height by 12 inches and converting to square feet. Note that when ice is included for the particular loading configuration, the thickness of ice is added to the bundle height for calculating wind loading.

Therefore, wind loading, in lbs/foot, is determined by:

$$Load_{wind} = (Height_{bundle} + 2 \times icethickness) \times \frac{12}{144} \times Pressure_{wind} \quad \textbf{(14)}$$

Cable bundle height, in inches, is determined by:

Case 1 - One cable lashed to a messenger,

$$Height_{bundle} = Dia_{cable} + Dia_{strand} \quad \textbf{(15)}$$

Case 2 - Two cables lashed to a messenger,

$$Height_{bundle} = Dia_{largestcable} + Dia_{strand} \quad \textbf{(16)}$$

Case 3 - Three or four cables lashed to a messenger,

$$Height_{bundle} = Dia_{bundle} \quad \textbf{(17)}$$

Bundle diameter is calculated for Case 3 as described in APPENDIX I.

APPENDIX III - PROCEDURE FOR ANALYZING SPANS WITH MORE THAN FOUR CABLES

For spans with more than four cables lashed to the messenger, calculations can be made using **SPANMASTER® RELEASE 2**, but some minor manual calculations are necessary.

The procedure consists of determining the total weight of the cables and the overall diameter of the cable bundle. This information is input into the position of CABLE 1. **SPANMASTER® RELEASE 2** treats the bundle as a single, large cable.

STEP 1) Sum the weights of the cables. Do not include the strand weight.
STEP 2) Determine the diameter of the cable bundle. This can be done by graphically constructing the cable bundle configuration or by physically measuring the bundle.
STEP 3) Input the total cable weight into the "WEIGHT" column of CABLE 1.
STEP 4) Input the bundle diameter into the "DIA." column of CABLE 1.
STEP 5) Input the strand information manually or by using "AUTO ENTER" as described in Section 4.1.
STEP 6) Manually input a "0" (zero) for the strand diameter. For large cable bundles, the strand is assumed to be "nested" between the cables and does not contribute to the overall bundle diameter.
STEP 7) Do not put any cable information into any other cable position. Cable positions 2, 3 and 4 should be blank. Do not specify Figure 8, that is, make sure the "Figure 8" cell contains an "N".

As an example, consider a span that consists of seven 1" P-3 cables. Total cable bundle weight is calculated and the overall bundle diameter is determined. After inputing the information into cable position 1, the input screen should appear similar to Figure 5.

NAME: Dylan Andrew DATE: 3/22/92 SPAN ID: Example #1
NOTES: Example showing manual input of bundle information for case of 7 P3 1" cables.

CommScope

Strand Input

DESCRIPTION	AREA (sq.in)	MODULUS (psi)	DIA. (in.)	EXP. COEFF. (1/F)	WEIGHT (lb/ft)	CREEP (in/in)
1/4" EHS	0.0352	2.60E+07	0.250	5.6E-06	0.121	0.0007

Cable Input (Up to 4 cables on the same strand)

DESCRIPTION	AREA (sq.in)	EFF.MOD (psi)	DIA. (in)	EFF.EXP (1/F)	WEIGHT (lb/ft)	FIGURE 8 CABLE?
CABLE 1 7-P3 1"			3.240		2.555	N
CABLE 2						N/A
CABLE 3						N/A
CABLE 4						N/A

Span Input Data

INSTALL. TEMP.(F)	SPAN (ft)	SAG (ft)	SAG (%)	MIN. SERV. TEMP.(F)	MAX. SERV. TEMP.(F)	Optional Clearance (ft)
60	180	1.5	0.8	-40	140	0.00

Figure 5 - Example of screen input area with bundle information input for 7 P3-1" cables.

APPENDIX IV - ASSUMPTIONS AND SOLUTIONS TO EQUATIONS

A. Assumptions:

- Calculations are based on horizontal spans.

- The parabolic approximation of catenary equations is used (see equations below). A general rule-of-thumb is that the error generated by this method is minimal for sags under 5% of span length.

- No equipment loadings are taken into account.

- The program does not automatically generate data for NESC Rule 250C, Extreme Wind Loading, 1990 Edition. This rule is applicable for structures 60 ft above ground or water level. Values can be input into the temperature and wind pressure cells to examine loading conditions other than those shown in Tables 1 and 2 in Section 5.5 of this manual.

- Except for Figure 8 cables, the strand is assumed to carry all the load. In a Figure 8 cable, the strand and the cable are considered to be integrated, and the load is distributed between them. The portion of the load carried by the cable depends on the strand/cable selection.

B. Equations:

Catenary Equation:

$$s = \frac{T}{W}\left(\cosh\frac{WL}{2T} - 1\right) \qquad (18)$$

where, s = sag at midspan (ft),
T = wire tension (lb),
W = load on the wire (lb/ft),
L = span length (ft).

The hyperbolic cosine can be expanded in a Taylor Series:

$$\cosh z = 1 + \frac{1}{2!} \cdot z^2 + \frac{1}{4!} \cdot z^4 + \frac{1}{6!} \cdot z^6 + \ldots . \qquad (19)$$

Using the first two terms of the Taylor Series as an approximation,

$$\cosh z \approx 1 + \frac{1}{2} \cdot z^2 \qquad (20)$$

Therefore, the Catenary equation can be approximated as:

$$s \approx \frac{T}{W} \cdot \left(1 + \frac{1}{2} \cdot \left(\frac{WL}{2T}\right)^2 - 1\right) = \frac{WL^2}{8T} \qquad (21)$$

Equation (21) is the parabolic (or second order) approximation.

Catenary length (L_c):

$$L_c = \frac{2T}{W} \cdot \sinh \frac{WL}{2T} \qquad (22)$$

Using the same approach used with Equation (18), Equation (22) can be approximated by:

$$L_c \approx L + \frac{8s^2}{3L} \qquad (23)$$

Other relationships used are:

Hooke's Law:

$$L_u = \frac{L_c}{\left(1 + \frac{T}{EA}\right)} \qquad (24)$$

where, L_u = unstressed length of wire (ft),

L_c = length of catenary (ft),
E = modulus of elasticity of the wire (psi),
A = cross sectional area of wire (in^2).

Definition of thermal expansion coefficient:

$$L_{uf}=L_{ui}\cdot(1+\alpha\Delta T) \tag{25}$$

where, L_{uf} = final unstressed length (ft),
L_{ui} = initial unstressed length (ft),
alpha = expansion coefficient ($^\circ F^{-1}$)
delta T = temperature change ($^\circ F$).

Rule-of-mixtures:

$$\alpha_{eff}=\sum\frac{A_iE_i\alpha_i}{A_iE_i}, \qquad E_{eff}=\sum\frac{A_iE_i}{A_i} \tag{26}$$

By manipulating these equations, a cubic equation for final sag (s_f) can be derived in the following form:

$$s_f^3+a\cdot s_f+b=0 \tag{27}$$

where,

$$a=\frac{3}{8}(L^2-L_{uf}\cdot L), \qquad b=\frac{-3L_{uf}W_fL^3}{64AE}$$

Solutions for the cubic equation are as follows:

$$s_f = \sqrt[3]{-\frac{b}{2}+\sqrt{\frac{b^2}{4}+\frac{a^3}{27}}} - \sqrt[3]{\frac{b}{2}+\sqrt{\frac{b^2}{4}+\frac{a^3}{27}}} \tag{29}$$

or

$$s_f = 2 * \sqrt{-\frac{a}{3}} * \cos\left[\frac{1}{3}\ Cos^{-1}\left(\frac{(-\frac{b}{2})}{\sqrt{(-\frac{a}{3})^3}}\right)\right] \qquad (30)$$

APPENDIX V - DEFINITIONS

bundled conductor - page 51 of The National Electric Safety Code - 1990 Edition defines bundled conductor as, "An assembly of two or more conductors used as a single conductor and employing spacers to maintain a predetermined configuration. The individual conductors of this assembly are called subconductors." Based on discussions with CATV and Utility industry consultants, this is not the correct definition to use for CATV applications to determine ice loadings. See Multiconductors.

cable assembly - the messenger and those components lashed to it. A typical cable assembly consists of a stranded wire messenger, one or more communication cables (coaxial or fiber optic), and lashing wire. Miscellaneous hardware that hangs from the messenger is ignored in this software.

clearance - The National Electric Safety Code - 1990 Edition defines clearance as "The clear distance between two objects measured surface-to-surface." (pg. 51). Clearance in the context of this program is the distance between the cable (or cable assembly) and a stationary object beneath the cable. The most common application is for clearance between the cable assembly and the ground.

creep - permanent deformation of a material that occurs at stresses below the yield point of the material. Metals stressed below yield point for short periods of time will recover when the stress is relieved. When the time period is sufficiently long, non-recoverable deformation occurs, called creep. In the context of "sag and tension", creep usually refers to the permanent elongation experienced by the messenger under load.

effective expansion coefficient - the coefficient of thermal expansion of the coaxial cable, calculated from the rule-of-mixtures using the properties of the various materials that constitute the cable.

$$\alpha_{eff} = \sum \frac{A_n \cdot E_n \cdot \alpha_n}{A_n \cdot E_n} \qquad (31)$$

where, A_n = area of a given component,
E_n = modulus of a given component,
$á_n$ = expansion coefficient of a given component,
$á_{eff}$ = effective expansion coefficient of the overall cable.

effective modulus - the elastic modulus of a the coaxial cable, calculated from the rule-of-mixtures using the properties of the various materials that constitute the cable.

$$E_{eff} = \sum \frac{A_n \cdot E_n}{A_n} \qquad (32)$$

where, A_n = area of a given component,
E_n = modulus of a given component,
E_{eff} = effective modulus of the overall cable.

figure 8 cable - a communications cable where the cable is integrated with a messenger during manufacture with an extruded jacket.

ice and wind loading - the load induced onto the cable assembly due to the added weight of ice and horizontal wind loading. **SPANMASTER® RELEASE 2** uses NESC guidelines to calculate the loading. See Section 5.5 for details.

messenger - the load bearing component of an aerial cable installation. Messengers normally consist of stranded, zinc coated steel wires and are covered by ASTM A 475-89 and ASTM A 363-89. Other types of messenger include solid, zinc coated steel wire and dielectric messengers of aramid yarn and fiber glass yarn.

modulus - in this document, modulus refers to elastic modulus for the strand or cable. Units are pounds per square inch (psi).

multiconductors - A definition of multiconductors is not provided by the NESC - 1990 Edition in Section 2. "Definitions" (pp. 50-62). However, Rule 251.A. discusses wind and ice calculations using multiconductors, a term generally used to refer to power cable configurations. In this software, ice and wind

calculations for CATV cable assemblies use the method described for multi-conductor cables. These methods are described in detail in Appendices I and II. See bundled conductor.

NESC - National Electric Safety Code, an American National Standard published by The Institute of Electrical and Electronics Engineers, Inc., Edition 1990.

sag - the vertical distance between the cable and an imaginary line connecting the termination points of the cable in a span. In **SPANMASTER® RELEASE 2**, sag refers to the maximum sag in the span, which occurs at span midpoint.

"Sag and tension" - term that collectively refers to techniques and practices used to analyze the mechanical behavior of cables and cable assemblies in aerial installations.

strand - commonly used term used to refer to the messenger in an aerial cable installation.

unloaded strand sag - the initial sag at which the messenger strand must be installed in order to achieve a final, target sag after the strand has been loaded (i.e., cables are lashed to the strand).

unloaded strand tension - the tension to which the messenger must be installed in order to achieve the target final sag and tension after the strand is loaded (i.e., cables are lashed to the strand).

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This construction manual has been written as a guide for construction practices. In no way can all the circumstances that may be encountered in the field be adequately addressed in this manual. Our intention in writing this manual is to provide information that will be useful in establishing construction specifications that are specific to the system being built. CommScope recognizes and respects the diversity of practices and opinions that exist related to the construction of CATV and broadband plant. Our opinions are not necessarily the opinions of the other professionals in the our field. If you have seen errors in this manual, or if you are critical of the opinions set forth in this manual, CommScope is interested in your comments. Please take the opportunity to write CommScope and communicate your opinions and comments. They will be considered when revisions are made to this manual. Please forward all communication to:

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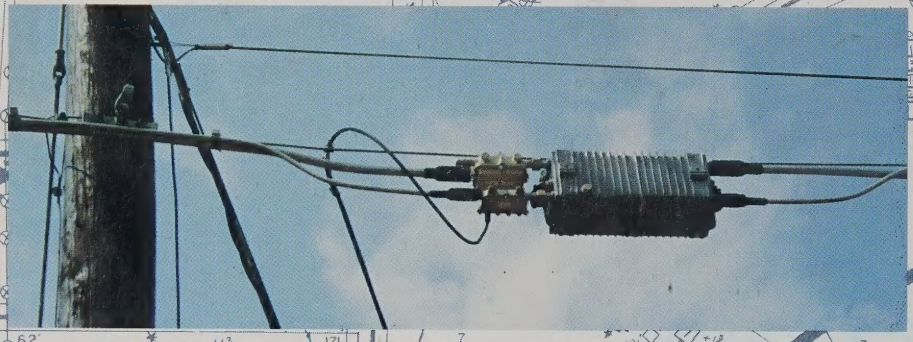

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